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'ENGLISH ELECTRIC'

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Electronic Reading Machines

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Bradford Institute of Technology

[Based on a lecture given before the Midlands Branch, on Wednesday, March 22, 1961.]

A MACHINE which is designed to recognise letters or symbols printed on a sheet of paper, and to perform some particular action corresponding to each particular symbol, is called a " character-recognition " or " print-recognition " machine.

Machines already exist which can be said, in a sense, to read the numerals 1 to 9 and 0. Such machines are, in fact, on the market, but practically all of them are severely limited in that they will read only figures, and perhaps a few symbols, and then only subject to some additional arbitrary condition. This condition may be, either, that the figures be printed in magnetic ink, or shaped in some rather grotesque way, or printed always in the same type-face, and be located at exactly the same position for each reading.

An example of a machine using either magnetic ink or specially shaped characters is the E.M.I. machine " FRED ".[1]

Figure reading machines are intended for feeding data into accounting machines and computers, and for reading bank cheques before sorting and recording them.

Machines at present available are large and expensive, the price of one American type being said to be about £18,000. Although this cost is so high, yet even this sum could eventually be recovered by a purchaser, because a good machine could replace human operators preparing the magnetic or punched paper tapes which are at present used for supplying the input to computers and similar machines.

The first electronic computer, as distinct from a mechanical or electro-mechanical one, was built in 1945 at the University of Pennsylvania. Since then, computers of a variety of types have been developed, and have of course been applied to a wide range of work. This has resulted in considerable research being done on the problem of devising a reading-machine to read numerals only, but a really satisfactory machine is still some years away.

The problem of character-recognition is not new, the first work being done about 1910. This, and, in fact, all the work published from then until about 1950 was, however, not related to problems of automatic computation, but was concerned with quite a different object, namely, that of devising a method of making the information on an ordinary printed page available to a blind person. This problem, which is in effect, " reading automatically to the blind " is the subject of this paper. In the paper, a description is given of some of the more important machines designed so far, and the development of the problem is outlined. Then follows a short discussion of the nature of the problem, as it can be envisaged at the present time.

It cannot be doubted that there is a great need for three different types of reading machine for the blind. First, a machine is required to transliterate printed matter into braille, and emboss it automatically. At present, this has all to be done by hand, and it is slow and expensive. The slowness and cost have the effect that the blind have no braille daily paper at all, and only a few weeklies. A machine of this kind, situated in a central publisher's works is badly needed.

Braille is difficult to learn, especially for older people, and most blind people are not blind until late in life. Of all the blind, now about 97,000 in this country, only 15 per cent can read braille, and of the 3,500 persons who are both blind and deaf, only 5 per cent.

Therefore, a second type of machine is needed to read both letters and words aloud, like letters and words read by a sighted person. Such a machine should be small and simple enough to be used regularly in the home.

Thirdly, a small portable machine to read single letters is required. This would enable blind persons to read commercial literature letter by letter, and so would extend the range of work which they can do in industry. A machine which approximately meets this need exists in an experimental form, and this is described below.

In early work on the problem, attempts were made to reproduce the printed letters by audible signals, for example, by chords of musical notes. Some devices aimed at reproducing the letters by raising a set of plungers through a metal plate, so transliterating the

letter on the paper into its braille equivalent. Thus the visual symbol was to be transliterated into an audible or tangible form.

Neither of these solutions to the problem can ever be really satisfactory. Even a very intelligent person has difficulty in distinguishing a sufficient number of different chords of the type produced by a reading machine. People lacking a " musical ear " find it particularly difficult, or even impossible. This is referred to again in connection with the Optophone, described below.

Reproducing the printed characters by simulated braille letters is also unsatisfactory because so few blind people can read braille.

The first reading machine was described in the *Proceedings of The Royal Society* in 1914 by E. E. Fournier d'Albe,[2] who had demonstrated it before the British Association in the previous year.

This was called the Optophone, and is shown in Fig. 1.

In this machine a rotating disk was used. This was drilled with eight concentric circles of small holes, the larger circles having more holes than the smaller. Behind the disk, an electric lamp having a straight-line filament was arranged with the filament parallel to a radius of the disk, so that in each circle only one hole at a time was illuminated. The prism and lens system thus produced an image which consisted of a vertical line of up to eight small spots of light, and this image was focused on the printed character to be read.

As the disk revolved it interrupted the light forming the images of the holes, the frequency of interruption being greater for the holes of the larger radius circles. Eight different frequencies of interruption were thus produced.

The light reflected from the paper fell on two selenium cells placed on either side of the character read. The output from these cells was supplied to a telephone receiver and a chord of eight notes was heard if all eight spots of light fell on white paper. Those spots which fell on black parts of the character were less strongly reflected so that their notes were of lower intensity. Thus, each letter was intended to be characterised by a chord of eight notes, less one or more notes in a unique combination characteristic of the letter. It will be obvious, however, that the actual chord itself must have varied as a letter passed under

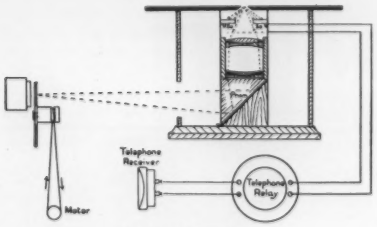

Fig. 1. *The Optophone.*

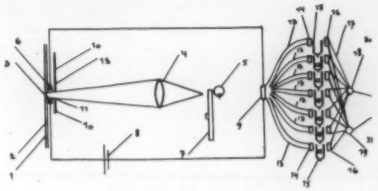

Fig. 2. *Butler-Burke's Transliterating machine.*

the images of the spots, because of the lack of symmetry in the letter about the horizontal axis.

The Optophone was extremely difficult to use, and a modern form of this instrument in use in 1950 had only four accomplished readers. These people reached a reading speed of approximately one letter per second, in spite of the fact that they were reported to be persons of high intelligence.

The next significant advance was made in 1924 by a Fellow of the Institute of Physics, named J. B. Butler-Burke.[3]

In this machine, shown in Fig. 2, each letter of the text in turn was to be framed in a rectangular hole, ((3) in the Figure) in a screen (2). This fact alone indicates a weakness in the idea, because letters vary in width between " i " and " m ", and it is not possible, with most type faces to single out by a frame of fixed width a narrow letter in the middle of a word. The suspicion is therefore aroused that Butler-Burke's machine was never actually constructed, or, at least, not as described in his patent.

The framed letter was " scanned " rather as in the Optophone. A combination of a straight narrow slit (not shown in Fig. 2) with a rotating disk (7), was used. The disk, shown in Fig. 3, was pierced with a set of seven concentric circular slots, the width of each slot varying sinusoidally.

The straight slit was arranged radially with respect to the disk so that a set of seven spots of light fell upon the letter framed. Then, the intensity of each spot

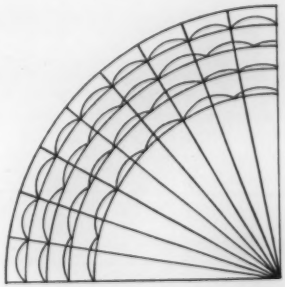

Fig. 3. *Butler-Burke's Scanning-disc.*

varied sinusoidally. The amplitude of the variation in the light reflected from the paper was reduced in the cases of those spots which fell on black areas of the letter.

Two selenium cells (6) received the summation of the reflected light and their output was fed to a telephone receiver (9).

The object of Butler-Burke's invention was to reproduce the printed matter (usually called "letterpress" in the present context) by typing it on an electrically operated typewriter, or by embossing it as braille. It was therefore necessary to analyse the output from the selenium cells to find a parameter uniquely characteristic of each letter scanned.

To do this, the sound from the telephone receiver (9), was fed through speaking tubes (13) to a row of telephone receivers (14), each of which was associated with a tuning fork (15). It was intended that these should vibrate in resonance with the notes of their own natural frequencies if present in the received sound. One prong of each fork was mechanically connected by a pin with the diaphragm of a microphone, and the outputs from these microphones were then mixed (!), amplified and analysed a second time—this time electrically in a chain of resonance circuits.

Butler-Burke assumed that for each letter scanned there could be found one particular harmonic of the electrical wave form produced by the selenium cells which would be uniquely characteristic of that letter. Therefore he fed the output from each resonance circuit to a particular key of the typewriter.

Several points in this invention show that it was probably never actually built. First, the energy available to excite the tuning forks would be far too small for this method of harmonic analysis to work. Secondly, the analysis is carried out twice over, quite unnecessarily, indicating that the patent represents only a very early stage in the development of the device. Thirdly, it is very doubtful if it is in fact practicable to characterise any considerable number of letters each by a single frequency.

Nevertheless, Butler-Burke's patent made a significant advance. He cites the use alternatively of a scanning disk having a spiral slot, which, rotating behind the radial slot mentioned earlier would produce a mechanical type of "flying-spot" scanner. Although a scanner of this type was invented by Nipkow in 1884, yet it was first applied to the present problem by Butler-Burke.

A second innovation was the idea that the character scanned should be reproduced by typing or by embossing, or some other action. Thirdly, and perhaps even more important, was the introduction of the idea of electrical or mechanical analysis of the electrical signal corresponding to the character to be read.

The next major attack on the problem was that of R. E. Naumberg[4] of Cambridge (Mass.), described in three patents about 1932.

Naumberg's machine was called the Visagraph and was intended to read letterpress and reproduce it in embossed form on aluminium foil.

A scanning disk, having six concentric circles of short slots equally spaced was used (Fig. 4). As in the Optophone, the letterpress was then scanned horizontally by (in the Visagraph), six spots of light which

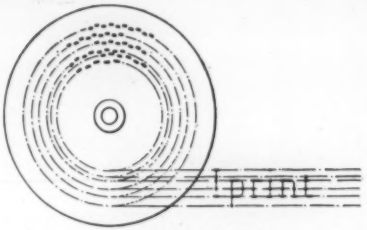

Fig. 4. *Naumburg's "Visagraph".*

were interrupted at different frequencies. The output from the selenium cells was fed to six tuned amplifiers, each of which, when excited at its resonant frequency, operated an electro-magnetic embossing plunger which then embossed a raised dot on the aluminium foil. If all six spots rested on a black part of the letterpress, the six plungers embossed a vertical line of six dots. As the letterpress moved under the line of light-spots and as the aluminium foil moved over the plungers, each plunger remained operated as long as the corresponding spot rested on "black". Thus the horizontals of the letters were embossed as continuous horizontal lines, but the verticals were embossed as vertical lines, broken into six dots. Fig. 5 shows the letters "o", "f", and "t" as they appeared when embossed.

Blind people found the Visagraph a little easier to use than the Optophone.

It is remarkable that this machine could have been made to print braille, using telephone relays and established circuitry which has never been patented, and yet Naumberg has completely missed this point.

We now come to what may be called "modern" work on this topic, because from 1945 inventors began to use the cathode ray tube, the photomultiplier tube and other devices of recent origin.

In the United States Flory and Zworykin[5] about 1944 devised a machine like the old Optophone. The perforated disk with its eight holes was replaced by a spot of light reflected from an oscillating mirror arrangement. This spot moved over the letter in vertical lines and so scanned it. As the spot moved upwards, an oscillator generated a note which rose in pitch in synchronism with the spot. Because of the short duration of the period spent by the spot on the "blacks", the user heard not a chord, but a series of thumps and clicks

Fig. 5. *The "Visagraph": the letters 'o', 'f', 't' as embossed.*

and these were the sounds which had to be distinguished. A maximum reading speed of ten words per minute was attained.

This work was an important advance for two reasons. The scanner was in the form of a probe which was held in the hand and moved over the paper manually. Secondly, the whole apparatus weighed only 5½ lbs. Here was the first approach to the desirable portable machine which could do so much to increase the independence of blind people in their daily lives.

In 1949 Zworykin, Flory and Pike[6] published a description of the first machine to recognize letters as well as numbers and repeat their names audibly as "A", "B" and "C".

These workers reverted to the Optophone method of scanning, using eight spots travelling in horizontal lines, but the spots were produced on the screen of a cathode ray tube and were projected by a lens on to the paper. As the light from each spot was alternately reflected from the white paper and absorbed by the black of the letterpress, so this sequence was examined for each spot in turn. The resultant interruption-pattern was fed to a set of eight channel-counters. A small computer element was used to arrange that particular combinations of channel-counters energized caused a particular magnetic-tape sound-track to be made to speak the name of the letter.

The inventors state in their paper that there was still ambiguity between certain letters, as between "b" and "d", and between "c" and "z". However, this was a valuable piece of work particularly because a normal type face, not a special one, was used.

The only other reading machine which seems to have been reasonably successful in recognising letters as well as numbers is that of D. H. Shepard[7] of the American Intelligent Machines Research Corporation, patented in 1953. This machine is actually on the market. It is apparently intended for feeding the input to accounting machines only.

As shown in Fig. 6, an image of the character to be read is focused on a rotating disk, which is divided into nine sectors. In each sector the disk is pierced with one or two small circular or short rectangular holes, in particular positions. The character is moved slowly across the apparatus whilst the disk revolves very rapidly. Behind the disk is a second lens-system and photoelectric cell. Each time a sector is aligned with the image of a character, light may or may not be reflected through the holes in the disk. If the black parts of the image coincide with the holes no light will pass through to the photocell, which thus remains un-energized and this is a signal for recognition of the letter.

Each of the nine sectors is thus aligned in turn so as to receive the image of the character. Each time a sector is so aligned without a corresponding energization of the photocell, a relay is operated and locks in the operated position. Thus, a particular combination of relays is operated according to the particular selection of sectors of the disk which give no energization of the photocell when receiving the image of a particular letter. The contacts of the relays are then cross-connected in the manner commonly used in automatic telephone circuitry to make connection with a particular output wire corresponding to the letter read. Shepard also

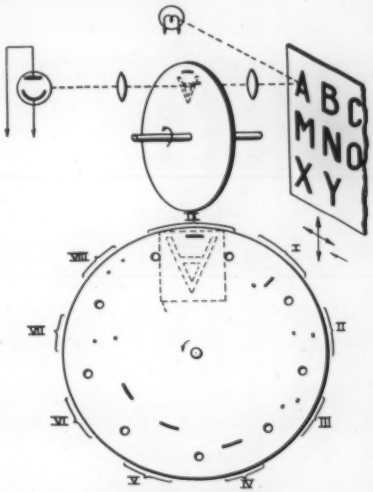

Fig. 6. *D. H. Shepard's Reading Machine.*

cites in his patent the possibility of using a Nipkow disk type of flying-spot scanner. In this case the output from the photo-electric cell will be recorded on magnetic tape and compared with records on a magnetic drum to identify the character. It is curious to see the disk scanner still in use in 1953.

A number of reading machines have been patented in which recognition is carried out by fitting an optical image of the character to the shapes of letters and figures cut out of a mask or plate of some kind. That of Schutkowski is described below. The method requires very accurate location of the character to be read, and this has proved an insuperable problem in most cases. Shepard's patent includes means for correcting the vertical alignment continuously. It is comparatively independent of horizontal misalignment because the nine sectors of the rotating disk "look" repeatedly at the character as it moves across the field of view.

Schutkowski[8] used a special type of lens which produced multiple images on a stationary screen of the letter before it. The screen had the shapes of all the letters of the alphabet pierced through it, and behind each piercing was a photo-electric cell. If the black image of a letter just filled a particular piercing, then the associated photo-electric cell became relatively non-conducting and a signal was therefore passed from it, through amplifiers, to operate a tape recording of the sound of the letter.

Finally, machines have been proposed in which an enlarged optical image of the character was to be focused

on a matrix of photo-electric cells. The combination of cells energized because they were receiving white parts of the image, was then to be used to identify the letter.

This method of recognition is not promising because it presents the old problem of exact location of the letter on the cell-matrix. Also because the image is enlarged the contrast between black and white is poor. Finally, the recognition of whole words would require a very large number of cells and something like a small computer to analyse the information. A machine of this type is that of Jannopoulo.[9]

Examples of all the more important types of solution of the reading-machine problem have now been described. As I have said, a machine of reasonable size and which is reliable and accurate has not yet been produced, but quite a lot of work is being done at present in several countries.

Let us now look at the nature of the general problem. There are three basic requirements.

First, the ultimate reading-machine must be able to recognize all the type-faces in common use for continuous text.

Second, it must be able to recognize whole words as well as letters and numerals.

Third, it must deliver its output at will, either as a reproduction from some type of recording of the sound of the letter or word read, or it must deliver it letter by letter in braille.

Other requirements which are very desirable are matters of mere development once the three basic needs are met. Amongst these are small size, and low-power consumption. These requirements can be partially attained by use of printed circuits and transistors. Next, the machine must automatically traverse from word to word along the line of type and from line to line down the page, so as to bring every word in turn into the area scanned. Finally, it must be simple to set up and operate.

Now, how are the basic requirements to be met?

The question of differing type-faces is of problematical importance. The number of widely differing faces actually used in the text of printed books is not large, and variations are generally about some average. Variations in size, width and height ought to be accounted for by focusing adjustments, and it ought to be possible to ignore serifs. One patent specification cites a sloping scan to take italic lettering into account.

The problem upon which inventors have concentrated has always been that of the conversion of the letter on the paper into an electrical signal. Three general ways of doing this have already been described. These may be given as:—

(1) Scanning by a row of spots, the spots being distinguished by notes of different frequencies,
(2) fitting an image of the letter to a shape cut out of a mask,
(3) forming an image of the letter on a matrix of photo-electric cells.

Zworykin, Flory and Pike, in their patent take a step forward because they use a cathode ray tube to generate the scanning spots so that they can control focusing and location electrically. The Solartron system uses a flying-spot type of scanner, but recognition involves use of a matrix built into the circuit of the machine.

In all cases in which a flying-spot scanner is used, one is always faced with far too much information taken from the paper and converted into electrical form. The problem is to extract what is essential and discard the remainder.

The second basic requirement is that of reading words. Here two alternative types of solution exist.

If an accurate machine recognizing letters exists, then it is in principle straightforward to select the sound-recordings of the words from a vocabulary of tape or film records because the technique required to do this is already known. One could use a circuit like that of an automatic telephone exchange. Each digit would be one of the letters " a " to " z " instead of a number " 1 " to " 0 " and trap-circuits would discriminate between such words as Tap, Tape and Taper.

The disadvantage of such a system would be simply the sheer volume of the apparatus.

Alternatively, the recognition part of the machine could be made to discriminate between words as such, as well as between letters. This would mean a very high resolving power with an error of less than one part in fifty thousand to make it possible to distinguish between such pairs of words as " constriction " and " construction ".

The final requirement is that of delivering the output in the form of words reproduced from a sound recording of some kind. The number of times any particular gramophone record, or tape or film is played is comparatively small over its whole life, but in a reading machine the number of playings for the more common words would be very high. The reason is that a reading speed of about three words per second is required, so the tapes or films would have to be continuously in motion. Both types of recording require the tape or film to be in physical contact with the sound head to make the articulation of the speech sufficiently good. This means friction, and therefore wear and a short life. The alternative of recording on glass disks as in the Post Office speaking clock would make the whole machine far too bulky. The solution here will probably be to take advantage of the restricted frequency range required for acceptable speech, and to use a tape arranged to float at a distance of not more than 0.001 in. from the pole pieces of the pick-up head.

A further problem here is that of access to the sound records. The scanning and recognition end of a print-recognition machine consists essentially of a single connection from the paper to the discrimination apparatus. But at some point, this single connection must divide, and be directed into any one of about twenty thousand paths to the twenty thousand sound records, assuming this to be the number of words in the vocabulary. The amount of apparatus in each of these paths must be kept to a minimum and should consist of no more than the sound-record itself. No system of access requiring, say, one valve, or one sound-head per word would be practicable. A difficult problem is therefore presented. It may well be that some entirely new method of sound-recording will have to be devised.

A machine fulfilling these requirements would come nearest to simulating a human reader, and I am convinced that nothing less will be sufficient. Such a

machine as this will still have one major disadvantage. It will read in a monotone. In experiments which I have carried out with blind people, however, I have found that after a few minutes this becomes acceptable, although it is inclined to become tiring after a long period. A minor disadvantage of any such machine will be the inevitable confusion between pairs of words such as " read " (infinitive) and " read " (past participle), and " invalid " (sick) and " invalid " (not valid). But such cases are very small in number, at least in English.

In spite of these inevitable disadvantages, however, a successful machine would still be a valuable aid in making life easier and more pleasant for the blind, particularly those who are also aged.

I wish to make acknowledgments for permission to reproduce the figures as follows:—

To The Royal Society for Fig. 1.

To The United Kingdom Patent Office for Figs. 2, 3, 4 and 5.

To The United States Patent Office and to Clyde C. Heasley, Jr., of Farrington Electronics Inc., U.S.A., for Fig. 6.

The actual sources of these figures are given in the references below.

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BRITISH NUCLEAR ENERGY SOCIETY

The first meeting of the above society will be held on

January 31, 1962

at 5.30 p.m.

at the Institution of Civil Engineers,
1-7 Great George St., London, S.W.1.

A PAPER ON

PLUTONIUM FUEL FOR NUCLEAR POWER

by

L. Grainger and A. B. McIntosh

will be read

SYNOPSIS

Plutonium is an inevitable by-product of the natural uranium reactors of the British Power Programme and is an artificial nuclear fuel of great potential value.

During the past decade, plutonium fuel technology has been developed within the Authority and a range of production, fabrication and processing techniques are now in advanced stages of investigation.

The technology covers a wide variety of plutonium fuels and takes account of their application in various reactor systems.

This paper reviews the substantial progress which has been made in recent years towards the efficient use of plutonium as an economic and reliable source of heat for nuclear power stations.

December 1961

Industrial Mathematics and National Certificate

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[The substance of a lecture delivered to a Ministry of Education Engineering Summer School held at Cranfield, July 1961.]

TWO ASPECTS OF MATHEMATICS

ALMOST everyone will agree that there are at least two quite different attitudes to Mathematics. To the pure mathematician it is an abstract discipline taught and studied for its own sake; to the physicist and engineer it is a tool to be used in the furtherance of their work and usually only capturing their interest when they see its practical possibilities. This sets the approach to mathematics which is adopted in National Certificate courses. Traditionally, little or no attempt at rigour is made; emphasis is on the so-called practical techniques. Nevertheless, mathematics is a formidable stumbling block to many otherwise promising physicists and engineers. Are we really doing all we can to maintain the student's interest and to equip him mathematically for his future needs ?

INDUSTRIAL MATHEMATICS

What branches of mathematics are being used in industry to-day ? If we look long enough and wide enough we can doubtless find almost any part of mathematics we care to name being used somewhere by somebody. We must concentrate attention on those topics which are in most common use. If we approach a man in industry, engaged in some mathematical work, and ask what he is doing he is most likely to mention, apart from elementary algebra, calculus, trignometry and the straightforward evaluation of formulae, one or other of the following: classical dynamics; vectors; integral transforms; algebraic equations and matrices; differential equations; numerical methods; statistics. If he is using equipment, it will be a slide rule, a desk calculating machine, a high-speed digital computer, an electronic analogue computer or some other analogue device. These are impressions based on experience of industry and discussions at mathematical conferences. A more detailed research which promises to be very interesting is to be carried out by Dr. Kerr of Salford College of Advanced Technology, financed by the Nuffield Research Foundation, into the industrial uses of mathematics in electrical engineering.

To enlarge a little on two of these topics: firstly, we all know that when Caley developed his matrix algebra in 1858, he said that here is a branch of mathematics which will never be of practical value. Yet if there is one branch of pure mathematics which is widely used in handling practical problems to-day, it is matrices. This is almost entirely due to the advent of high-speed computers, as of course, is the tremendous surge in industrial mathematics generally. Computers like to carry out a cycle of simple operations over and over again; this is just what is called for in matrix manipulation and so there is a tendency to use matrix methods whenever possible; e.g. in solving large sets of algebraic equations (even partial differential equations are reduced to sets of algebraic equations and handled by matrix methods); in stability studies of numerical methods of solving differential equations; in circuit analysis by electrical engineers.

Secondly, the use of numerical methods generally has also been stimulated on a large scale by computers. It is not only that so often a practical problem can be solved in no other way but also that the solution is wanted in numerical or graphical form anyway if it is to be of practical value so why not plan and work in numbers from the start ? Why do a lot of complicated algebra followed by a lot of tedious arithmetic when the problem can be handled arithmetically by a computer throughout ? And so the trend is towards arithmetic on a vast scale.

EFFECTS ON EDUCATION

To what extent should the education of a physicist be influenced by these mathematical developments in industry ? Much publicity has been given in recent months to the shortage of mathematicians in teaching. This is largely due to the fact that industry is employing many more mathematicians than ever before; but it has been said frequently that what industry really needs is engineers and physicists with a good mathematical background, who are so equipped mathematically that they can handle industrial problems or at least know what problems can profitably be taken to a mathematician and can help him to formulate them. Are we providing the right sort of mathematics and presenting it in the best way in National Certificate courses ? It is often said that although scientists and engineers study a lot of mathematics, none of it is useful in industry. We are all aware that there is a tendency already to cram too much information into National Certificate students. It is not realistic to add other topics unless something is removed or more time is made available, perhaps in endorsement courses. Maybe it is in Higher National Diploma courses that modifications should be tried out first. Let us look, however, a little more closely at one or two ways in which some time can be saved.

INTEGRATION

There is a tendency sometimes to spend a lot of time on this topic, to some extent perhaps because it is a fruitful field for examination questions. Clearly the student must be taught the basic techniques of simple

substitution, changing the variable, integration by parts, partial fractions and the substitution of limits in definite integrals. Once he understands these, however, instead of being given intensive drill in the evaluation of large numbers of integrals in order that he may memorize the procedures he could be introduced to tables of standard substitutions and integrals and taught to use them in practical problems. After all, this is the way in which he will almost certainly deal with an integral once his examination is over, should he ever be fortunate enough to meet one which could be dealt with by these standard techniques.

DIFFERENTIAL EQUATIONS

Why do we still teach the operator D and all the confusion of complementary functions and particular integrals ? This is textbook stuff; hardly anyone uses these methods after he has qualified. If this part of the syllabus were removed it could be replaced by a simple introduction to Laplace transforms. All that is needed is to define the transform, to obtain the transform of one or two simple functions by integration, and to show how a table of transforms can be used to solve an ordinary differential equation. This is an approach which can be extended later should the student wish to tackle more difficult problems and which is used by practising engineers and physicists in dealing with real problems. An indication of the application of Laplace transforms to electric circuit analysis would give an added incentive to some students.

TAYLOR'S SERIES

All students meet Taylor's series, but the only use to which most of them are asked to put it is to evaluate for example sin 31° without using tables. A more artificial example is difficult to imagine; no practising physicist is likely to find sin 31° in this way. Taylor's series, however, provides a very practical method of obtaining a numerical solution of a differential equation and one which is extensively used by high-speed computers. A brief glimpse of this application would help the student to see Taylor's series as something of practical importance. The series can also be used to obtain finite-difference approximations to first and second derivatives which are used in numerical integration. These could even be examples for the student to work.

MATRICES

We have referred to the widespread use of matrices in industry. If we suggest that they have a place in Higher National Certificate courses this does not imply the full pure mathematician's treatment. There is a very good case, however, for introducing the elementary ideas of matrices at an early stage. In fact, there is a lot of discussion among mathematicians at the present time as to whether matrices should be introduced into secondary school mathematics. Simple manipulation including addition, multiplication and inversion with an application to the solution of a set of algebraic equations would suffice. Time could be more profitably spent in this way than in the evaluation of determinants by various tricks of the trade. Again, for many electric circuit problems the power of the matrix analysis of networks makes it an almost indispensable approach.

STATISTICS

This subject plays a vital role in physics and electrical engineering. What industrialists seem mostly to require is that students should have sound basic ideas of probability and the statistical approach. They should be aware that variance exists and has to be coped with. An understanding of these basic ideas is far more important than the churning out of means and standard deviations, necessary though this is. In teaching these routine calculations, the opportunity can be taken, however, to emphasize the importance of using a standard lay-out and a systematic checking procedure in any computation.

NUMERICAL METHODS

This topic is the one which probably springs to most people's minds when revision of courses in the light of industrial experience is mentioned. Numerical methods have come into their own with the high-speed computer; at what level and to what extent they have a place in education ? This is a very wide question which is exercising many minds at the present time and to which a final answer will only be reached after some years of experimenting. What do we find in existing National Certificate syllabuses. Most of them include the direct evaluation of formulae; solution of algebraic equations by determinants; Simpson's rule, Newton's iterative method for the improvement of a root, and the least-squares fitting of data.

The first thing to note is that almost invariably these processes, which involve a good deal of arithmetic, are carried through with the aid of tables of logarithms—a time consuming method wholly out of date; a slide rule is a perfectly respectable example of the use of logarithms as well as being a good practical tool. There must be few colleges which cannot afford such simple equipment as this; in fact, many are now buying desk calculating machines which, of course, are necessary if higher accuracy is required.

The second point is that with no extra time at all some of these topics can be used to illustrate the importance of lay-out, systematic working and checking which are the backbones of computation. Take Simpson's rule for example. Often we see the calculations strung in a single line across the page: a more professional lay-out is indicated by the example below.

Evaluate $\int_{50°}^{56°} \log \sec x \, dx$

$x°$	log sec x	multiplier	product
50	0·19193	1	0·19193
51	0·20113	4	0·80452
52	0·21066	2	0·42132
53	0·22054	4	0·88216
54	0·23078	2	0·46156
55	0·24141	4	0·96564
56	0·25244	1	0·25244
			Sum 3·97957

$$\int_{50°}^{56°} \log \sec x \, dx = \frac{1° \times 3{\cdot}97957}{3} = 1{\cdot}3265 \text{ to } 4D$$

Other topics can be extended slightly and given fresh interest. In dealing with Newton's formula, for example, the idea of an iterative process should be referred to as a general method of calculation. Also, an interesting example of the use of this formula is the evaluation of successive approximations x_1, x_2 to $\sqrt{\alpha}$ according to the following scheme:

$$f(x) = x^2 - \alpha = 0;\ f^1(x) = 2x,\ x_2 = x_1 - \frac{f(x)}{f'(x)}$$

$$= x_1 - \frac{x_1^2 - \alpha}{2x_1} = \tfrac{1}{2}(x_1 + \alpha/x_1).$$

With regard to the solution of algebraic equations by determinants this is not a satisfactory method in practice, since much more labour is involved than is the case with other methods such as systematic elimination, relaxation or a matrix method.

If more time can be found for numerical methods, what is wanted first of all, even at Ordinary National level, is an appreciation of the new way of looking at mathematics which Numerical Analysis involves and of the basic structure of the whole rather than detailed treatments of small areas.

(1) Numerical Analysis provides convenient methods for performing *open numbers*, mathematical operations such as square rooting, differentiation, integration, and of solving equations of all kinds directly *in numbers*.

This is a new attitude; school teaching leads to the idea of the algebraic symbol and formulae as the mainstays, but *numbers* are what practising physicists and engineers really need.

(2) The main tenets of Numerical Analysis are:
(*a*) Systematic lay-out
(*b*) Estimation of error and controlled accuracy
(*c*) Checking against blunders.

(3) Students should come to realize that methods of calculation exist which are quite different in type, namely (*a*) Direct, (*b*) Iterative, (*c*) Step-by-step.

Some general instruction in the use of mathematical tables is basic. Excellent references are Chambers Shorter 6 Figure tables; Interpolation and Allied Tables; Barlow's Tables. Useful introductory textbooks are *An introduction to computational methods* by K. A. Redish (E.U.P. 1961), and *Numerical Analysis for Science and Engineering* by R. G. Stanton (Prentice-Hall 1961). *Modern Computing Methods* (second edition) written by members of staff of the Mathematical Division, N.P.L. and issued by the Stationery Office, 1961, will be useful to the lecturer.

A more systematic approach to Numerical Methods should be possible in Higher National Diploma courses at least. Basic topics are an introduction to differences and their use in the detection of mistakes, interpolation, integration and differentiation, simple error analysis and the solution of algebraic and differential equations. Though the main topics are in a little doubt there is a good deal of room for speculation about the order in which they should be treated. There may be considerable resistance to the numerical approach from the students who may see it merely as an additional burden unless its practical value can be brought home to them. If it can be associated with the evaluation of the results of their laboratory experiments, well and good. Alternatively, it may be possible to shock them into realizing the uselessness, from a practical point of view, of some so-called solutions obtained by traditional methods. Take for example the differential equation

$$\frac{dy}{dx} = \frac{y-x}{y+x}$$

with the condition $y = 1$, $x = 0$. Students are taught to spot that this equation is homogeneous, to substitute $y = vx$ and after some manipulation to obtain what they call a solution, namely

$$\tfrac{1}{2}\log_e(x^2+y^2) + \tan^{-1}\frac{y}{x} = \frac{\pi}{2}.$$

But in a practical situation a solution should be something which tells us the value of y for a given value of x. The students can profitably be left awhile with the above expression in order that they may realize its worthlessness from this point of view. Then would be the psychological moment to introduce them to a step-by-step method of obtaining a numerical solution. The very simple procedure set out below would enable the lecturer to talk about step-by-step methods of calculation in general and to indicate that this is the way in which high-speed computers tackle the problem.

Solve $\dfrac{dy}{dx} = \dfrac{y-x}{y+x}$ with $y = 1$ when $x = 0$.

The calculations to proceed in steps $\delta x = 0{\cdot}02$.

At $x = 0$

$$\delta y = \frac{dy}{dx}\,\delta x = \frac{y-x}{y+x}\,\delta x = \frac{1-0}{1+0}\,(0{\cdot}02) = 0{\cdot}02.$$

Hence $y_1 = y_0 + \delta y = 1{\cdot}02$.

At $x = 0{\cdot}02$

$$\delta y = \frac{y-x}{y+x}\,\delta x = \frac{1{\cdot}02 - 0{\cdot}02}{1{\cdot}02 + 0{\cdot}02}\,(0{\cdot}02) = 0{\cdot}0192.$$

Hence $y_2 = y_1 + \delta y = 1{\cdot}02 + 0{\cdot}0192 = 1{\cdot}0392$.

The most convenient working arrangement is as below

x	y	$y+x$	$y-x$	$\dfrac{y-x}{y+x}$	$\delta y = \dfrac{y-x}{y+x}\,\delta x$
0·00	1·0000	1·0000	1·0000	1·000	0·02000
0·02	1·0200	1·0400	1·0000	0·962	0·0192
0·04	1·0392	1·0792	0·9992	0·926	0·0185
0·06	1·0577	1·1177	0·9977	0·893	0·0179

There is a tendency to think that numerical methods can only be understood after traditional mathematical methods have been explored. That this is a misconception is powerfully illustrated by a consideration of partial differential equations usually regarded as one of the more difficult branches of mathematics. Suppose we have a problem in heat flow. Traditionally we distinguish the following steps in the solution:—

(i) we set up a partial differential equation,
(ii) we get a solution by separation of variables, or
(iii) by Laplace transforms.

The former method of solution involves Fourier series, the latter error functions, complex variable and contour integration. In other words, we have a vast edifice of pure mathematics between the statement of the problem and its solution. Let us look at an alternative approach taking a simple example by way of illustration. Suppose we have a tube of unit cross section along which is a temperature gradient and hence a flow of heat.

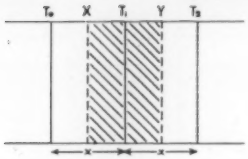


Fig. 1

Consider the shaded element of thickness x considered small in Fig. 1 between the dotted sections at X and Y. The heat balance equation for the element is

Heat entering through section at X
− heat leaving through section at Y
= heat accumulating in element,
all in time t,

i.e. $K/X\,(T_0 - T_1)t - K/X\,(T_1 - T_2)t = c\rho x(T_1' - T_1)$, where T_1' is the temperature after time t, K is the heat conductivity, c the specific heat and ρ the density. Thus

$(Kt/c\rho x^2)\,(T_0 - 2T_1 + T_2) = T_1' - T_1$.

In the special case $Kt/c\rho x^2 = \frac{1}{2}$,

$T_1' = \frac{1}{2}\,(T_0 + T_2)$.

This means that given the temperature at any time we can build up a temperature distribution at a small time, t, later by applying this relationship at successive points along the tube, and so proceed in small steps t to any subsequent time. All we have used is one basic definition from physics and some arithmetic; we have short circuited the mathematical edifice. This is broadly speaking the way a computer tackles a heat flow problem so we have provided a growing point from which the student can develop further his knowledge of modern practical methods if he wishes.

MATHEMATICAL LABORATORY

The place of a mathematical laboratory and an indication of some of the equipment to be included, have been discussed quite fully in an earlier article—the *Bulletin*[1]. Most of what is written there is highly relevant to National Certificate and Diploma students. The importance of the laboratory lies for them very largely in that it helps to present mathematical processes in concrete form and to show how physical and engineering situations are expressed mathematically. It helps to take away the too-abstract nature of mathematics which generates in many practically-minded students a great dislike of the subject.

A mathematical laboratory should contain a good collection of reputable mathematical tables, reference books, tables of integrals, etc. Slide rules have already been mentioned. Many colleges are now equipping themselves with desk calculating machines and these are really essential if any systematic numerical work is to be attempted. It would be rash to predict how long it will be before National Certificate students are writing programmes for high-speed computers. Certainly this cannot replace an understanding of basic mathematical progress and techniques but we may well find that the computer can be used to demonstrate some processes and economize on time. In any case it is equipment about which all students nowadays should know something.

The teaching aspect is more advanced in relation to analogue equipment. Both mechanical and electrical analogue computers are valuable pieces of demonstration equipment. A particularly suitable demonstration is that of the solution of the well-known differential equation for damped oscillations. The nature of the solution and the effect on it of varying different parameters such as mass, damping coefficient, etc., can be quickly and convincingly demonstrated. Conducting sheet and resistance network analogues of heat flow problems are useful adjuncts to the teaching of relaxation methods. Not all equipment need be expensive by any means. There is great scope for ingenuity on behalf of staff and students. Corresponding demonstrations of statistical principles are equally desirable. A good mathematical laboratory is a place in which the mathematics comes alive for the students.

Some colleges already include in their syllabuses most of the suggestions put forward in this paper. There are, however, considerable differences between the various colleges. Some perhaps are less favourably placed than others to know which of the many topics that could be included in National Certificate and Diploma syllabuses are most likely to be profitable to the students in the long run. This article has been written in the hope that it will provide useful guidance.

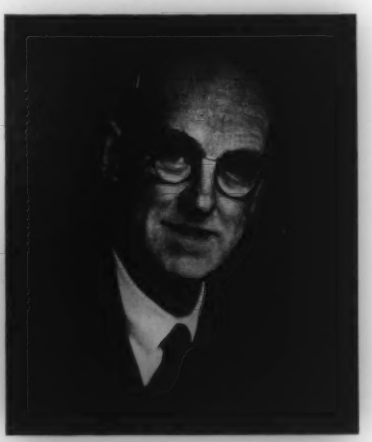
REFERENCES

(1) J. R. Barker and A. Porter. *The Role of a Mathematical Machines Laboratory in Education.* Institute of Physics *Bulletin 10* (1959), 277

Obituary

Professor A. M. Tyndall, C.B.E., F.R.S., Hon.F.Inst.P.

As was briefly reported in the November *Bulletin*, Professor A. M. Tyndall died quietly in his sleep on October 29, at the age of 80.



Born in Bristol in 1881 Professor Tyndall was a student at the University College, Bristol, and joined its staff in 1903. He continued to serve the College, which became the University of Bristol, as lecturer and, from 1919, as Professor until his retirement in 1948, and continued to have a close and active interest in the University and the Physics Department, to the great pleasure of his successors, right up to his death. No one disputes that the great reputation in physics which Bristol now enjoys was built up by his ability to choose men and to inspire and support them.

Professor Tyndall was a Founder Fellow of The Institute of Physics, served on the Board from 1933 to 1936, was a Vice-President in 1945 and President 1946-48. He continued to serve on the Board until 1952 and in 1953 was elected to Honorary Fellowship, the highest honour that members of the Institute could bestow. Until the year of his death he had continued to serve on the Membership Committee and regularly attended its meetings, where his presence contributed to the humour as well as to the efficiency of the usually lengthy proceedings. He was also for some years one of the two permanent members of the Interview Panel and an examiner for the Graduateship examination. Professor Tyndall's service to the Institute was not, however, measurable by any list of offices held and perhaps only the permanent officers, who saw him more frequently than did anyone else, were in a position to know just what his wise judgement and kindly advice contributed to the growth of the Institute.

Professor Tyndall served physics and physicists, as well as his University, with great enthusiasm, integrity and critical judgement. He received most of the honours that go to distinguished scientists, and one that goes to very few: there can be few men to whom it is given, as it was given to Professor Tyndall, to know that, without consciously seeking it, they have acquired in an emphatic and unmistakeable way not only the respect but the warm affection of their fellows. In the *Bulletin* some years ago Professor E. G. Cox wrote of his exceptional good fortune in " having come under the influence of two such men as A. M. Tyndall and W. H. Bragg, not only great scientists but lovable human beings ". To anyone privileged to have known Professor Tyndall it would be impossible to write in any other terms.

N. C.

Notes and News

Problems facing university physics departments

The Committee set up by Council to prepare a report on problems facing university physics departments has made excellent progress. It has conducted a survey of all university physics departments, obtaining information about staff, student numbers, research, finance, etc., and has had more than twenty professors at meetings to give oral evidence. Representatives of Colleges of Advanced Technology have also attended a meeting. As part of its task the Committee is preparing evidence for the Robbins Committee on Higher Education. The composition of the Council's committee is Professor R. V. Jones (University of Aberdeen) (Chairman), Professor B. Bleaney (University of Oxford), Professor C. C. Butler (University of London), Sir John Cockcroft (University of Cambridge), Professor G. K. T. Conn (University of Exeter), Professor A. W. Merrison (University of Liverpool), Professor A. B. Pippard (University of Cambridge), Professor M. H. L. Pryce (University of Bristol), Dr. J. Topping (Brunel College of Technology), Dr. F. A. Vick (Atomic Energy Research Establishment), Professor J. G. Wilson (University of Leeds) with Mr. N. Clarke as Secretary. The final report should be available early in the New Year.

Committee on Physics Education

At the request of The Royal Society, on the suggestion of the British National Committee for Physics, the

Institute and Society has appointed a British Committee for Physics Education which has extremely wide terms of reference permitting it to take such steps as it sees fit to try to improve physics education in this country at any level. The Committee consists of the following: Professor N. F. Mott (University of Cambridge) (Chairman), Dr. N. F. Astbury (The British Ceramic Research Association), Sir Lawrence Bragg (Royal Institution), Professor C. C. Butler (University of London), Dr. J. Goodier (Eton College), Mr. B. Holmes (University of London Institute of Education), Mr. J. Lewis (Malvern College), Professor H. Lipson (Manchester College of Science and Technology), Dr. J. Topping (Brunel College of Technology) and Professor D. A. Wright (University of Durham) with Mr. Clarke as Secretary.

Physics Teaching in Schools

There is now widespread interest in various proposals that have been made for the improvement of physics courses in schools. One of these proposals, represented by the new syllabus recommended by the Science Masters' Association, is now the subject of an experiment conducted with some 500 children, with the co-operation of the Ministry of Education. In order to provide members with the opportunity of learning of different views on this somewhat controversial subject, a number of articles have been specially invited for the *Bulletin*. It was originally intended to publish these in one special issue but the amount of material finally available is too great for this; instead, the articles will appear in the first two or three issues of the next volume.

List of members

Arrangements have now been made for the publication of a new list of members early in the New Year, to include all full members, i.e. members of the three professional grades and other Fellows of The Physical Society. The preparatory work is very heavy but each full member will shortly receive a copy of the proposed entry for him and will be asked to make any necessary corrections.

Change of Group names

The Non-Destructive Testing Group will henceforth be known as the Materials and Testing Group and the Applied Spectroscopy Group will be known as the Spectroscopy Group. The Council has approved corresponding changes in the scope covered by these Groups.

Payment of subscriptions

As usual, members not paying by bankers' order are asked to delay sending their annual fees until they receive the January *Bulletin* in which a form will be included.

Members' copies of journals

All members who subscribed in 1961 to any of the Institute and Society's three monthly scientific journals or to the publications of the Institution of Electrical Engineers through the Institute and Society will be assumed to be requiring these in 1962 unless cancellations are received at Belgrave Square by December 31. Payment should be made in January, using the form enclosed with the January *Bulletin*.

In 1962 the special price for *Physics Abstracts* will be increased to 50s. a year, *Electrical Engineering Abstracts* to 30s. a year, and there will be a slight increase in the price of other Institution of Electrical Engineers' publications. Members paying by bankers' order will be asked later for the balance due.

Dr. B. P. Dudding

Dr. Bernard P. Dudding, Honorary Secretary of The Institute of Physics from 1946 to 1956, retired from the staff of the General Electric Co. Ltd., at the end of October after more than 42 years service. He was one of the first members of the staff of the G.E.C. Research Laboratories, joining Mr. C. C. (later Sir Clifford) Paterson at the end of the first world war. The photograph shows Mr. O. W. Humphreys, Technical Director of the General Electric Co. Ltd., and a Past-President of The Institute of Physics, presenting a cheque to Dr. Dudding.

Layout of the Bulletin

From January next the layout of the *Bulletin* will be improved and a larger size of type will be used. The size of page will be unchanged.

Christmas holiday

The offices of the Institute and Society at Belgrave Square and Lowther Gardens will close on Friday, December 22, in the early afternoon and reopen on Wednesday, December 27.

Summer Conference on Spectroscopy in the Metallurgical Industry

The Spectroscopy Group of the Institute and Society in conjunction with the British Non-Ferrous Metals and British Iron and Steel Research Associations is arranging a summer conference on "Spectroscopy in the Metallurgical Industry" to be held in Buxton, Derbyshire, from July 5-6, 1962. Anyone who wishes to give a short paper to the conference should get into touch with the Honorary Secretary of the Group, Dr. L. Bovey, Building 329.2, A.E.R.E., Harwell, Nr. Didcot, Berks. Further details and application forms will be distributed to members of the Spectroscopy Group early in 1962, and may be obtained by others on application to the Administration Assistant of the Institute and Society.

THE INSTITUTE AND SOCIETY

is arranging

a Conference on

The Ionosphere

in Londonon July 2-6, 1962

Main sessions and opening speakers :

Ionospheric constitution and ionizing radiations
Dr. H. Friedman (*U.S. Naval Research Laboratory, Washington*)

Geomagnetism and the ionosphere
Dr. C. O. Hines (*Defence Research Telecommunications Establishment, Ottawa*)

Irregularities in the ionosphere
Dr. B. H. Briggs (*Cavendish Laboratory, Cambridge*)

Mathematics of ware propagation through the ionosphere
Professor H. G. Booker (*Cornell University, U.S.A.*)

Offers of contributions accompanied by an abstract of 100-150 words should be sent to the Chairman of the Organizing Committee, Mr. J. A. Ratcliffe, F.R.S., Radio Research Station, Ditton Park, Slough, Bucks, before March 1, 1962.

The proceedings of the Conference will be published.

Accommodation will not be provided; intending participants are advised to book hotel accommodation early in the New Year. Further details and application forms will be available from the Administration Assistant of the Institute and Society in March, 1962.

The Institute and Society is arranging
a Symposium on

HIGH ENERGY NUCLEAR PHYSICS

to be held in

The Physics Department of Imperial College of Science & Technology

from

March 26-27, 1962

Several review lectures on both theoretical and experimental topics in high-energy nuclear physics will be included in the program. A limited time will be devoted to short communications. Authors of short papers who would like to be included in the program should send abstracts of their work to Professor C. C. Butler, Physics Dept., Imperial College, London, S.W.7, by January 1, 1962.

It is unlikely that residential accommodation will be available at the College, consequently, intending participants are advised to seek hotel accommodation in good time.

Further details may be obtained from the Administration Assistant of the Institute and Society, during December, 1961.

The Institute and Society in collaboration with the Joint British Committee for Vacuum Science and Technology is arranging a one day Symposium on

Some aspects of vacuum science and technology

at the

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, LONDON

on

JANUARY 5, 1962

The scope of the symposium will be:

Continuously exhausted bakeable vacuum apparatus for pressures below 10^{-9} mm. of mercury.

Communications regarding the program should be addressed to the Honorary Symposium Secretary, Mr. D. S. Richards, Department of Mathematics and Physics, The Polytechnic, 309 Regent Street, London, W.1.

Further details and application forms are available from the Administration Assistant of the Institute and Society.

THE BRITISH RADIO SPECTROSCOPY GROUP

jointly with

THE LOW TEMPERATURE GROUP of The Institute and Society

are arranging a conference on

SPINS and PHONONS

to be held at the H. H. Wills Physical Laboratory, University of Bristol, from April 16 to April 18, 1962. The subject matter will include the mechanisms of spin lattice relaxation in solids, cross relaxation, ENDOR, the interaction of acoustic waves with spin systems and the effect of spin scattering on lattice thermal conductivity. Speakers will include Professor B. Bleaney, Dr. A. H. Cooke, Professor M. H. L. Pryce Dr. H. M. Rosenberg, Dr. E. B. Tucker and Professor J. H. Van Vleck.

Intending contributors are invited to submit abstracts of their papers not later than January 15 to :

Dr. P. M. Llewellyn,
H. H. Wills Physical Laboratory,
University of Bristol

Accommodation will be available at one of the University Halls of Residence. Further information and registration forms will be available from the Administration Assistant of the Institute and Society in February, 1962.

Reviews of Books

CLASSICAL MECHANICS

By H. C. Corben and Philip Stehle

London and New York: John Wiley & Sons Ltd. Pp. xi + 389. Price 96s.

The authors of this book are theoretical physicists who have included under the title of classical mechanics many of the applications of the mechanics of Newton, Lagrange and Hamilton to physical problems. In this second edition, they have introduced the theory of space-charge limited currents, the motion of meteoric dust, variational principles in rocket motion as well as other special topics, and the final chapter on the orbits of particles in high energy accelerators has been completely re-written. The penultimate chapter of the book gives a very condensed presentation of some features of the special theory of relativity, but all the other chapters deal with non-relativistic classical mechanics.

The whole of the treatment is from a sophisticated mathematical point of view, but modern physical applications are kept well in mind. Vectors and matrices are used throughout. There are chapters on Hamilton's equations, the Hamilton-Jacobi method, infinitesimal contact transformations and further development of transformation theory.

Honours students in theoretical physics and post-graduate students in physics will find it a helpful volume.

J. Topping.

MODERN MATERIALS—ADVANCES IN DEVELOPMENT AND APPLICATION

Volume II.

Edited by Henry H. Hausner

New York and London: Academic Press Inc. (London) Ltd. Pp. xv + 413. Price 89s. 6d.

This is the second in a series of books dealing with modern materials: the first dealt with wood, synthetic rubbers, fibre materials, high voltage insulation papers, special glasses for nuclear engineering, modern ceramics, germanium, silicon and zirconium. The present volume covers polymer modified papers, flame-sprayed ceramic coatings, ceramics for cutting purposes, borides, titanium metallurgy, welding materials and soldering materials. It is certainly beyond the present reviewer to deal with all these topics critically, but it is a great merit of the book that he has been able to read all the contributions, whether on familiar topics or not, with the liveliest interest. They are well-written and bear the unmistakable mark of the enthusiast, and there are extensive lists of references.

The opening paragraph of the article on the fabrication of borides by Robert Steinitz is worth quoting because it aptly sets the background for the whole work. "Modern technology", he writes, "has made special demands for the development of new materials. There is no longer any material which has only a laboratory interest; as soon as it has been prepared, and as soon as some properties have been determined then, doubtlessly, an application for it will be found. There is always a place into which a new material can fit". One must applaud this philosophy, even if one must acknowledge privately that these things don't always happen in practice.

As a prodigious user of paper, your reviewer was humbled to find how little he knew of this commonplace commodity, and he must commend very highly to those in a like position the chapter on "Polymer Modified Papers" by Edwin C. Jahn and V. Stannett. This deals with wet-strength papers, special papers, plastic-coated papers and paper-based laminates. Data are given for the effects of additives like melamine formaldehyde, urea formaldehyde and phenolic resins on wet-strength. Elastometer-treated papers are required for purposes ranging from various types of packaging to shoe manufacture (alas. the paper sole, albeit a very sophisticated affair technologically, is a reality !), and their behaviour is assessed in terms of tensile strength, bursting strength, tear resistance and folding endurance. For plastic-coated papers, permeability to gases is an important physical property. Finally, the use of polyamide and acrylic fibres, instead of natural cellulose fibres, is briefly described.

The chapter on flame-sprayed ceramic coatings (N. N. Ault and W. M. Wheildon) deals with techniques which are being tentatively applied in a number of fields. The processes now, after a history going back nearly 50 years, fall into two main groups: the powder atomization process and the solid atomization process. There is at present only one practical version of the latter—the "Rokide" process in which a ceramic rod is fed through the gas burner: the other methods depend upon feeding powders into a gas flame or an arc plasma or upon coating by explosive combustion. Ceramic coatings can be obtained from a large number of oxides —alumina is now well-known—and some carbides, borides and nitrides. The article discusses the nature and texture of the coating, its physical properties and summarizes some of the limitations, the most important of which are the finite permeability and porosity and the difference between the coefficients of thermal expansion of the coating and the substrate.

W. M. Wheildon also contributes the chapter on ceramic cutting-tools. The essential material for these is alumina: the variants on this are numerous and it is interesting to note that one of the most successful complexes known to the reviewer is not in fact mentioned in this chapter. This may be a matter of commercial secrecy. The development of the ceramic cutting-tool cannot be divorced from the production engineering problems, and Mr. Wheildon's competent review takes good account of this.

The next two chapters are on borides: the first (Bertil Aronsson) is a comprehensive survey of the crystallography and phase equilibria of metal-boron systems which in itself is a valuable work of reference but in some ways out of tune with the rest of the book. The chapter (R. Steinitz) on fabrication, properties and applications of borides takes us through the particular applications of the general techniques of powder ceramics—hot pressing, cold-pressing, and sintering and

slip casting. Some borides can be flame-sprayed. Borides have high hardness, high strength at elevated temperatures and high melting-point. They have low electrical resistivity and high thermal conductivity. The transverse rupture strength at room and high (1000°C) temperatures is comparable with that of silicon carbide, but the data given suggest that they are very brittle, having a critical strain of less than 0·05%.

A substantial chapter on titanium metallurgy, almost as specialized in its way as the chapter on the basic factors of borides, is followed by one on welding materials and one on soldering materials. These are mutually complementary and cover the whole field of joining metal to metal very thoroughly.

The contributors to and the editor and publishers of this book are to be congratulated on an excellent production, which should find a place in the library of every industrial research laboratory.

N. F. Astbury.

MODERN PHYSICS FOR THE ENGINEER

Edited by L. N. Ridenour and W. A. Nierenberg

London: McGraw Hill Publishing Co. Ltd. Pp. xv + 383. Price 74s.

Like some other books this is unusual. It is not just another watered down elementary textbook on modern physics (whatever that signifies) thrown to the engineering wolves, but a collection of essays based on lectures by a series of masters. There are chapters on new particles by Segrè and Alvarez, on nuclear shell structure by M. G. Mayer, electron scattering and nuclear structure by Hofstadter and on electrons and nuclei in ideal crystals by Houstoun. Then there are chapters on liquid helium (Pellam) and superconductivity (Tinkham) followed by a treatment of magnetohydrodynamic waves by Baños, which completes the first part of the book, i.e. on the Laws of Nature.

Part 2, Man's Physical Environment, comprises three chapters, i.e. the origin of nuclear species by means of nuclear reactions in stars (Fowler), radio astronomy (Bracewell) and the origin of the earth's magnetic field (Elsasser). The final section of the work, Part 3, on technology includes chapters on controlled thermonuclear fusion (Colgate and York), nuclear reactors (Mills), particle accelerators (R. R. Wilson) and finally frontiers of aerodynamic research (Smelt).

The treatment, as is only natural in a work of this kind, is a little uneven from chapter to chapter but generally of a very high class and the book is to be highly recommended.

J. D. Craggs.

SPACE ASTROPHYSICS

Edited by William Liller

London: McGraw-Hill Publishing Co. Ltd. Pp. viii + 272. Price 77s. 6d.

The classical limitations of astronomy from the Earth are absorption, refraction and scattering of light by the atmosphere. The energetic photons in ultra violet radiation are absorbed by electronic transitions in the gases of the upper atmosphere while excitation of vibrational and rotational states of molecules lower down makes heavy inroads on the infra-red radiation. Irregular refraction due to density variations gives rise to stellar twinkling and limits angular resolution, while Rayleigh scattering of starlight and all too often dust scattering and artificial light sets a limit on the useful exposure times available for the study of the faintest sources.

Analogous effects arise in radio astronomy as a result of absorption, refraction and scattering of radio energy in the ionosphere.

Some improvements in the infra-red region may be obtained by means of balloon borne instruments, together with a substantial reduction in the effects of irregular refraction of visible radiation but over a very large part of the electromagnetic spectrum observation is only possible if the equipment can be carried beyond the appreciable atmosphere. Since the first detection of solar X-radiation by emulsions carried aloft on V-2 rockets after the last war a steadily increasing use has been made of vertical sounding rockets and later satellites to study parts of the spectrum inaccessible from the ground.

Naturally, the sun was the first object of study but later observations have been made of the moon, stars and gaseous nebulae using unstabilized sounding rockets. Improving technique, however, now makes it possible to use rockets and satellites with stabilizing equipment of great accuracy, with a result that a new era in astronomy is about to start.

Space Astrophysics is based on a course of lectures given at the University of Michigan in 1959-60. The authors of the various chapters are internationally acknowledged experts in the field.

Three sections deal with some experiments carried out to date, some theoretical astrophysics to which the future results of space astronomy experiments have special relevance and some instrumentation problems currently being tackled.

The book is well produced (though in typewriter type face) and very well illustrated. It is to be recommended to all scientists wishing to become acquainted with the kind of work being done.

R. L. F. Boyd.

PHYSIQUE ATOMIQUE ET CONNAISSANCE HUMAINE

By Niels Bohr. Translated by E. Bauer and R. Omnes.

Paris: Gauthier-Villars et Cie. Pp. 98. Price 15 NF.

The name of Niels Bohr needs no introduction to physicists. His contributions to atomic and nuclear physics and their applications in the utilization of nuclear energy are manifold and universally recognized. What are less well-known are his ideas concerning the relation of science, physics in particular, to the humanities. In this little book, lectures given on this general theme during the period 1932 to 1957 are reprinted together and they show in a remarkable way the depth and breadth of fundamental thought achieved by Bohr in problems of philosophy, physics and life, the unity of knowledge, and so on. The discussion with Albert Einstein on epistemological problems of atomic physics makes exciting reading. The translation into French is clear and readable. In short this is a book for the gourmet.

C. A. Hogarth.

RIPPLE TANK STUDIES OF WAVE MOTION

By W. Llowarch

London: Oxford University Press. Pp. vi + 66. Price 15s.

Mr. Llowarch's monograph is the vehicle for some 50 excellent ripple-tank photographs illustrating the various aspects of wave-propagation, with particular reference to the teaching of geometrical and physical optics. He begins by discussing the propagation of water-waves, pointing out that the analogy with light-waves breaks down over the matter of dispersion, and mentioning the theoretical limitations of extending the analogy to other forms of wave-motion. He also demonstrates the practical difficulties of showing to an audience a faithful picture of the water surface, whether by simple shadow or focused image; and he has satisfied me that the shortcomings that have appeared to afflict many quite tolerable commercial products are genuine defects, and not my own subjective reactions to their intricacy and price. Mr. Llowarch does not attempt the almost impossible task of focusing an optical image. Instead, he uses the Schlieren technique, so that we see reproductions of the actual surface disturbances. The book is very good value, and will be an asset to the teacher and to the science library. As I read it, I was reminded of Andrade's detailed study of Kundt's tube, and the way in which Searle's analysis made one almost ashamed to look a simple prism in the face; it is in that class—a revelation of what elementary apparatus can do in the hands of a physicist.

G. R. Noakes.

DIGITAL DATA

By D. S. Evans

London: Hilger & Watts Ltd. Pp. 82. Price 15s.

With the increasing importance being attached to digital methods of computation, due, in large measure, to the rapid development of electronic digital computers, it is natural that there should be much interest in digital methods of measurement. Mr. Evans' little book describes some mechanical, optical and electronic methods of measuring in digital form. The exposition is clear and readable and the illustrations and diagrams copious and excellent. He is to be congratulated on providing this brief, but surprisingly comprehensive coverage of the subject.

A. S. Douglas.

A TEXTBOOK OF PHYSICS

By R. C. Brown

London: Longmans, Green and Co. Ltd. Pp. xxi + 1424. Price 60s.

In his preface the author says the book is intended to be a straightforward presentation of the principles of physics to approximately the standard required by the Advanced level of the G.C.E. He succeeds admirably. The text is very thorough and rarely presupposes any previous knowledge of physics at all. Particularly for this reason it is an excellent textbook for those who take up the study of physics late in their school career.

There are a few omissions, Kirchoff's laws, the resonant a.c. circuit, and the theorem of perpendicular axes are notable among these. The McLeod gauge is treated very cursorily.

Sound, heat and light are very thoroughly done. In light the R.P. convention is used, and a simple method of fixing the sign of the radius of curvature of a spherical refracting is given. In heat it would be better if Leslie's cube with boiling water were omitted.

The approach to the study of electricity is unconventionable, the theory of electrostatics being done before the classical experiments such as Faraday's ice-pail are described. For those interested in the M.K.S. units a good chapter on units and dimensions is included. In modern physics the text just about covers the new syllabus in physics proposed by the Science Masters' Association in collaboration with the Institute and Society.

There is an ample supply of questions at the end of each chapter. The answers are to be found at the end of the book together with an excellent index. The complete volume is too bulky for class use, but several copies would be useful on the shelves of the Science Sixth.

R.M. Lee.

SCIENCE IN SPACE

Edited by Lloyd V. Berkner and Hugh Odishaw

London: McGraw-Hill Publishing Co. Ltd. Pp. x + 458. Price 54s. 6d.

It might be feared that this title is a concession to tastes which have been debauched by popular misuses of the word "space"; but hidden within the book are some articles of outstanding ability containing material important to serious physics and not easily found elsewhere. For instance the chapter on the Nature of Gravitation brings into a single discussion Mach, Einstein, Dirac, Bondi, and even the gamma-ray experiments of Mössbauer on relativity.

Some of the astronomical chapters are too brief and risk becoming abstracts of well-known treatises. But the treatment of magnetic acceleration of ions between sun and earth is especially valuable, with sections by Van Allen the discoverer of the outermost ion-belts around the earth, by Simpson the investigator of solar modulation of cosmic rays, and by Parker who has done much to elucidate interplanetary magnetic fields. A brief final chapter on extraterrestial biology is suggestive but probably suffers inevitably from compression in this physical set of essays.

Throughout the book, the authors have evidently been given a mandate to be thorough and careful in devising diagrammatic expositions, as these are excellent everywhere.

Martin Johnson.

THE STABILITY OF MOTION

By N. G. Chetayev. Translated from the Russian by Morton Nadler

Oxford: Pergamon Press Ltd. Pp. viii + 200. Price 60s.

The many developments in physics and engineering, in which feed back loops are involved have brought in their train questions of stability of increasingly complex systems. Such problems cannot be discussed satisfactorily by approximate methods, and as a consequence there has been an increasing interest among physicists

and engineers as well as mathematicians in the precise mathematical techniques for investigating such questions.

Much of the mathematical theory has existed since the beginning of the century, but its importance is only now being realized.

The present volume starts from the representation of the physical system by a system of differential equations. It is essentially a text on those aspects of the theory of differential equations which are relevant to the discussion of stability, and one of its basic aims is to present in a simple manner the main results of Lyapunov from his monograph *The general problem of the stability of motion*, which was first published in 1892.

The book contains a lot of interesting material on linear and non-linear differential equations illustrated by numerous examples, and will be a useful book for anyone interested in the subject. It is a translation of the second edition, published in Moscow in 1955. One must remark that even for these days the price is rather high though reasons for this are advanced in a publisher's notice.

A. W. Gillies.

PLASMA PHYSICS. Second revised edition.

By J. G. Linhart

Amsterdam: North Holland Publishing Co. Pp. xi+278. Price 50s.

This is the second edition of a work I reviewed in the *Bulletin* previously. There do not appear to be any major alterations or additions but the misprints and errata, which were neither numerous nor very important, in the first edition have now been corrected in the text. Despite the lapse of time since the first edition was available this remains one of the best works on the subject of plasma physics and in particular high temperature discharges, although it is a little disappointing that the new work of the last year or so has not been at least summarized. In particular there has been much new experimental and theoretical work on instabilities and on magnetohydrodynamical conversion of energy, and there is still a need for an all embracing authoritative and critical treatment of discharge temperature measurement.

J. D. Craggs.

ELEKTROMAGNETISCHE FELDER. EIN LEHRBUCH DER THEORETISCHEN PHYSIK

By Wilhelm Macke

Leipzig: Akademische Verlagsgesellschaft Geest & Portig K.-G. Pp. xvi+393. Price DM 29.50

Although this book is designed to stand on its own, it is in fact the fourth of six volumes covering the whole of theoretical physics. The titles of the other volumes are instructive — *Mechanics of Particles, Systems and Continua; Waves; Quanta; Thermodynamics and Statistics; Quanta and Relativity*. The whole is in the great German tradition of Planck and Sommerfeld although, if this book is typical of the whole, it must be conceded that while Planck and Sommerfeld were artists and virtuosos, Professor Macke, though exceedingly competent, is but a craftsman.

The book is written entirely in MKSA units, which leads on the very first pages to a not entirely successful struggle with Coulomb's law. This appears to be unavoidable and raises the question whether Gaussian units are not more suitable for a treatment that is to be both rigorous and axiomatic. Then comes a real stroke of genius. To introduce the difficult ideas of a force field, so strange initially to students, the author briefly treats point mechanics and the mechanics of continuous media from the point of view of both action at a distance and also field theory. Having thus had the new ideas explained to him on well established physics, the student is ready for the discussion of new phenomena.

After that the book is a little disappointing. We are led painstakingly, exhaustively and at times exhaustingly through electro- and magnetostatics; conductors, insulators, magnetic materials and electric currents; the magnetic effect of an electric current; and electromagnetic induction. There are hosts of examples, many worked out in full, most of which in this country would not appear outside the more old-fashioned types of applied mathematics courses. Nature and physics hardly seem to exist until suddenly at the end of the chapter on induction there appears, incongruously, a long and detailed section on particle accelerators. This is not the way to show that one is up-to-date. Only after this do we meet Maxwell's equations, which after all contain as special cases all that went before. (Sommerfeld puts them on p. 12 in his book !). A final chapter on relativity theory and the Lorentz group completes the book.

This is not a bad book and, if one wants to have everything spelt out in full, it is actually quite a good book, much better certainly than most similar textbooks in the English language. But one tends to lose the marvellous sweep of a theory which is one of the supreme achievements of the human mind. With Sommerfeld—and Landau and Lifshitz—available, Macke can only be recommended as supplementary study, to fill in the details where the great artists have used a brush stroke too bold for the tyro to appreciate.

L. R. B. Elton.

INTRODUCTORY MANUAL ON THE CONTROL OF HEALTH HAZARDS FROM RADIOACTIVE MATERIALS

Committee on Protection against Ionizing Radiations. Medical Research Council Memorandum No. 39

London: Her Majesty's Stationery Office. Pp. vi+21. Price 1s. 9d.

This short booklet, which is largely the work of Mr. W. Binks and Dr. W. G. Marley, is the successor to the manual of the same name produced by a Medical Research Council sub-committee shortly after the war. It is essentially an introductory manual; specialists in hospitals, factories, etc., being referred to their own regulations for detailed information. Nevertheless a large amount of useful information, in a readily understandable form, is packed into its 21 pages.

J. M. Valentine.

BOOK REVIEWS PUBLISHED IN OTHER INSTITUTE AND SOCIETY PERIODICALS

PROCEEDINGS OF THE PHYSICAL SOCIETY

(Vol. 78, August 1, 1961)

Time Series Analysis, by E. J. Hannan.
Variational Principles in Dynamics and Quantum Theory, 2nd edn., by W. Yourgrau and S. Mandelstam.
Nuclear Photodisintegration, by J. S. Levinger.
High Energy Nuclear Physics, by W. O. Lock.
Soviet Research in Geophysics, Volume 3, *Microstructure and Macrostructure*, by B. N. Ivakin.
Ionization Phenomena in Gases, by Gordon Francis.
Resonance Absorption in Nuclear Reactors, by L. Dresner.
Imperfections in Crystals, by H. G. van Bueren.
Cartesian Tensors: an Introduction, by G. Temple.
Nuclear Fusion—The Second Geneva Series on the Peaceful Uses of Atomic Energy, edited by W. P. Allis.
Royal Society Mathematical Tables, Volume 7, *Bessel Functions*, Part III, *Zeros and Associated Values*, edited by F. W. J. Olver.
Annual Reports on the Progress of Chemistry, Volume LVI, 1959.
Solid State Physics, Volume 11, edited by F. Seitz and D. Turnbull.
Neutron Detection, by W. D. Allen.
Stochastic Processes, Problems and Solutions, by L. Takács.

(Vol. 78, September, 1961)

Angewandte Gitterphysik, 3rd edn., by W. Kleber.
Atomic Theory for Students of Metallurgy, by William Hume-Rothery.
Physics of the Upper Atmosphere, edited by J. A. Ratcliffe.
High Energy Electron Scattering Tables, by R. Herman and R. Hofstadter.
Graphite and its Crystal Compounds, by A. R. Ubbelohde and F. A. Lewis.
From Dualism to Unity in Quantum Physics, by Alfred Landé.
The Hydrogen Bond, by G. C. Pimentel and A. L. McClellan.
Field Theory of Guided Waves, by R. E. Collin.
Théorie des Groupes en Physique Classique et Quantique, Volume I, *Structures Mathématiques et Fondements Quantiques*, by Th. Kahan.

(Vol. 78, October, 1961)

Plasma Physics, a course given by S. Chandresekhar at the University of Chicago. Notes compiled by S. K. Trehan.
Relativity: The General Theory, by J. L. Synge.
Solid State Physics, Volume 11, *Advances in Research and Applications*, Supplement 2, *Paramagnetic Resonance in Solids*, by W. Low, edited by F. Seitz and D. Turnbull.
Quantum Theory of Atomic Structure, Volume 1, by J. C. Slater.
Progress in Nuclear Physics, Volume 8, edited by O. R. Frisch.
Studies in Theoretical Physics: The Proceedings of the Summer School of Theoretical Physics held at Mussoorie, India, on May 22–June 18, 1959, Part 3.
Proceedings of the 1960 Annual International Conference on High Energy Physics at Rochester, edited by E. C. G. Sudarshan, J. H. Tinlot and A. C. Melissinos.
Annual Review of Nuclear Science, Volume 10, edited by E. Segrè, G. Friedlander and W. E. Meyerhof.
Some Ionospheric Results obtained during the International Geophysical Year, Proceedings of a Symposium organized by the URSI/AGI Committee, Brussels, 1959, edited by W. J. G. Beynon.
Elektronenbegung, by Ernst Bauer.
Theoretical Physics in the Twentieth Century: A Memorial Volume to Wolfgang Pauli, edited by M. Fierz and W. F. Weisskopf.
An Introduction to Astro-Dynamics, by R. M. L. Baker, Jr., and M. W. Makeson.
Principles of Optics, by M. Born and E. Wolf.
Kybernetik, Band 1, Heft. 1 — Journal dealing with the transmission and processing of information and with control processes in organisms and automata.
Selected Scientific Papers, by B. van der Pol, edited by H. Bremmer and C. J. Bouwkamp.
The Rotation of the Earth, Cambridge Monograph on Mechanics and Applied Mathematics, by W. H. Munk and G. J. F. MacDonald, edited by G. K. Batchelor and S. Goldstein.
Complex Variables and the Laplace Transforms for Engineers, by W. R. Le Page.
Proceedings of the International Conference on Nuclear Structure, edited by D. A. Bromley and E. W. Vogt.
Physique Nucléaire, by M. Bayet.
Physics of the Atom, by M. Russell Wehr and James A. Richards, Jr.
Frozen Free Radicals, by G. J. Minkoff.

BRITISH JOURNAL OF APPLIED PHYSICS

(Vol. 12, September, 1961)

Physical Methods in Chemical Analysis, Volume 1, 2nd revised edition. Edited by Walter G. Berl.
Analogue Computers, by I. I. Eterman.
Lichtstrahl-Oszillographen, by W. Härtel, J. Degenhart, A. Kübler, C. Sörensen and J. Tröger.
Werkstoffe für Elektrische Kontakte, by A. Keil.
Elsevier Monographs: Electrostatic Separation of Mixed Granular Solids, by O. C. Ralston.
Lectures on Communication System Theory, edited by E. J. Baghdady.
A Short History of Technology, by T. K. Derby and Trevor I. Williams.
Kinetics, Equilibria and Performance of High Temperature Systems—Proceedings of the First Conference Western States Section, The Combustion Institute 1959, edited by G. S. Bahn and E. E. Zukoski.
Electrothermie, edited by M. Pirani.
Thermolectricity, edited by P. H. Egli.
Infrared Methods: Principles and Applications, by G. K. T. Conn and D. G. Avery.
Interferometry—National Physical Laboratory Symposium. No. 11.
Mechanics and Properties of Matter, 2nd edn., by R. J. Stephenson.
The Mechanics of Vibration, by R. E. D. Bishop and D. C. Johnson.
An Introduction to the Theory of Vibrating Systems, by W. G. Bickley and A. Talbot.
An Introduction to Applied Anisotropic Elasticity, by R. F. S. Hearmon.
Large Elastic Deformations and Non-Linear Continuum Mechanics, by A. E. Green and J. E. Adkins.
Impact: The Theory and Physical Behaviour of Colliding Solids, by W. Goldsmith.
Mechanical Waveguides, by M. R. Redwood.
Techniques of Non-destructive Testing, edited by C. A. Hogarth and J. Blitz.
Ultrasonics, by B. Carlin, 2nd edn.
X-ray Microscopy. Cambridge Monographs on Physics, by V. E. Cosslett and W. C. Nixon.
Progress in Semiconductors, Volume 5, edited by A. F. Gibson, F. A. Kröger and R. E. Burgess.
Progress in Nuclear Energy, Series IV. Technology, Engineering and Safety, Volume III, edited by C. M. Nicholls.
Kernenergie Technik, by H. Engel and K. O. Thielmann.
Fast Neutron Physics: Part I. *Techniques. Interscience Monographs and Texts in Physics and Astronomy*, Volume IV, edited by J. B. Marion and J. L. Fowler.
Controlled Thermonuclear Reactions—An Introduction to Theory and Experiment, by G. Glasstone and R. H. Lovberg.
Materials for Nuclear Engineers, edited by A. B. McIntosh and T. J. Heal.
Nuclear Propulsion, edited by M. W. Thring.
Eléments de physique Nucléaire, by D. Blanc and G. Ambrosino.
Radioisotope Laboratory Techniques, 2nd edn., by R. A. Faires and B. H. Parks.
The Radio Noise Spectrum, edited by D. H. Menzel.
Small Particle Statistics, 2nd edn., by G. Herdan.
Field Computations in Engineering and Physics, by A. Thom, C. J. Apelt and G. F. J. Temple.
Plasma Physics, by J. E. Drummond.
Wave Propagation in a Turbulent Medium, by V. I. Tatarski, translated by R. A. Silverman.
Einführung in die Theorie der Abtaststyteme, by J. Tschauner.
Vacuum Technology Transactions. Proceedings of the Sixth National Symposium, edited by C. R. Meissner.
Molecular Distillation, by G. Burrows.

(Vol. 12, October, 1961)

Essentials of Dielectromagnetic Engineering, by H. M. Schlicke.
Progress in Cryogenics, Volume 3, edited by K. Mendelssohn.
Non-Crystalline Solids, edited by V. D. Fréchette.
Nuclear Reactor Containment Buildings and Pressure Vessels—Proceedings of a Symposium organized by the Department of Mechanical, Civil and Chemical Engineering of The Royal College of Science and Technology, Glasgow, May 17 to 20, 1960.
Mathematical Handbook for Scientists and Engineers, by G. A. Korn and T. M. Korn.
Magneto-Fluid Dynamics, edited by F. N. Frenkiel and W. R. Sears. Proceedings of a Symposium sponsored by the International Union of Theoretical and Applied Mechanics in Co-operation with the National Academy of Sciences-National Research Council.
Physical Gas Dynamics, by A. S. Predvoditelev.
Technische Strömungslehre, by Bruno Eck.
An Introduction to Astronomy, by R. H. Baker.
Cobalt Monograph, edited by Centre d'information du Cobalt.
Nuclear Instruments and Methods, edited by K. Siegbahn.

(Vol. 12, November, 1961)

Nondestructive Testing, by W. J. McGonnagle
Introduction to the Dynamics of Automatic Regulating of Electrical Machines, by M. V. Meerov.
X-ray Metallography, by A. Taylor.

JOURNAL OF SCIENTIFIC INSTRUMENTS

(Vol. 38, November, 1961)

Transistor Circuit Analysis, by M. V. Joyce and K. K. Clarke.
Das Messen mit Elektrischen Geraten. Grundlagen und Anwendungen, by H. Neumann.
Textures in Metal Sheets, by F. A. Underwood.
Gas Chromatography. A Symposium held under the auspices of the Analysis Instrumentation Division of the Instrument Society of America, June, 1959. Editors H. J. Noebels, R. F. Wall, N. Brenner.

Forthcoming Institute and Society Meetings

December 18 at 7.00 p.m. AT MANCHESTER. Manchester and District Branch.
A musician looks at physics by Mr. F. R. Cox, O.B.E., Hon.R.A.M. (*Royal College of Music*). At The University.

December 21 at 2.30 p.m. AT LONDON. Optical Group.
Image formations by mirror-pair systems by Dr. H. H. Hopkins (*Imperial College of Science and Technology, London*).
The Okayama Astronomical Spectrographs by Dr. D. G. A. Demaine (*Hilger and Watts Ltd., London*). At The Imperial College.

January –. AT GLOUCESTER. South Western Branch.
SCHOOLS' LECTURE on **Automation** by Professor E. B. Pearson, F.Inst.P. (*Royal Military College of Science, Shrivenham*).
Date and time to be announced later.

January 5. AT LONDON.
SYMPOSIUM on **Some aspects of vacuum science and technology.** At Imperial College.
Registration is necessary.

January 10 at 7.00 p.m. AT LIVERPOOL. Liverpool and North Wales Branch.
The physics of computer elements by Dr. C. N. W. Litting, F.Inst.P. (*University of Manchester*). At The University.

January 12. AT LONDON. Materials and Testing Group.
DINNER MEETING followed by an informal address on **Photography** by Dr. H. Baines (*Kodak Ltd., London*). At the "Horseshoe Hotel".
Tickets are necessary.

January 15 at 7.00 p.m. AT MANCHESTER. Manchester and District Branch.
The cosmological problem by Dr. G. J. Whitrow (*Imperial College of Science and Technology, London*). At The University.

January 15 to 19. AT LONDON.
46th Exhibition of scientific instruments and apparatus. At the Royal Horticultural Society's Halls.
Admission by ticket only, available from The Secretary.
During the exhibition the following lectures will be given in the lecture room above the New Hall:

January 16 at 5.45 p.m.
A Physicist looks at music by Dr. C. A. Taylor, F.Inst.P. (*Manchester College of Science and Technology*).

January 18 at 5.45 p.m.
The uses of elasticity in instrument design by Professor R. V. Jones, C.B., C.B.E., F.Inst.P., F.R.S.E. (*University of Aberdeen*).

January 17 at 2.00 p.m. AT LONDON. Acoustics Group.
SYMPOSIUM on **The calibration of microphones and hydrophones** by Mr. E. Aspinall and Mr. A. M. Ratsey (*Post Office Research Station, London*), Dr. R. B. Newman (*Admiralty Underwater Weapons Research Establishment, Portland*) and Mr. H. S. Leman (*Standard Telecommunications Laboratory, Harlow*). At the Royal Horticultural Hall.

January 17 at 7.00 p.m. AT BRISTOL. South Western Branch.
Irradiation effects in nuclear reactor materials by Mr. R. S. Barnes, F.Inst.P. (*Atomic Energy Research Establishment, Harwell*). At the College of Science and Technology.

January 17 at 2.30 p.m. AT LONDON. Low Temperature Group.
GROUP ANNUAL GENERAL MEETING followed by a lecture on **Crystal lattices of semiconductors at low temperatures** by Dr. D. H. Parkinson (*Royal Radar Establishment, Malvern*) and others. At Headquarters.
Further details to be announced later.

January 17 at 6.30 p.m. At Birmingham. Midland Branch.
Development in vehicle and street lighting by Mr. V. J. Jehu, A.Inst.P. (*Road Research Laboratory, Harmondsworth*). At the Engineering and Building Centre.

January 18 at 6.00 p.m. At London. Stress Analysis Group.
Report on visit to the U.S.A. by Mr. V. M. Hickson, A.Inst.P. (*Royal Aircraft Establishment, Farnborough*). At Headquarters.

January 19 at 6.00 p.m. At Newport. South Wales Branch.
The limits of perception and measurement by Professor A. M. Taylor, F.Inst.P. (*University of Southampton*). At the College of Technology.

January 23 at 5.30 p.m. At London. Electronics Group.
Hot-electron emission from semiconductors by Dr. E. A. Davies (*Associated Electrical Industries (Manchester) Ltd.*). At Headquarters.

January 23 at 7.30 p.m. At Middlesbrough. North Eastern Branch.
The electrical synthesis of music by Mr. A. Douglas (*Bendix-Ericsson*). Joint meeting with the Society of Instrument Technology.

January 25 at 7.00 p.m. At Bristol. South Western Branch jointly with the Institution of Metallurgists.
Recent developments in non-destructive testing by Mr. R. S. Sharpe, A.Inst.P. (*Atomic Energy Research Establishment, Harwell*). At the College of Science and Technology.

January 25 at 6.00 p.m. (Tea at 5.30 p.m.). At London. London and Home Counties Branch.
The future of reactors by Mr. P. W. Mummery, F.Inst.P. (*A.E.R.E. Winfrith*). At Headquarters.

Manuscripts accepted for publication in the Institute and Society's periodicals

British Journal of Applied Physics

CONFERENCE REPORT

Proceedings of the Symposium on Tunnel Diodes, London, February 1961. By I. G. Cresswell.
The meeting covered the theory, physical characteristics and circuit applications of tunnel diodes, and the proceedings constitute a summary of the eight papers delivered.

Problem of materials for composite models in photoelastic frozen-stress work. By J. R. Dixon.
The particular problems arising when using composite models in dissimilar materials for frozen-stress work are discussed. Properties of birefringent materials suitable for simulating composite structures of steel, cast iron and aluminium are given. The photoelastic properties of a new Bakelite epoxide resin have been investigated.

Ionization chamber technique for studies of excited states and angular correlation of fission fragments. By L. R. Khare and R. R. Roy.
The angular correlations between the directions of emission of gamma rays of energies 0·7 mev and 1·3 mev and associated fission fragments were studied by a special electronic technique in conjunction with a multigrid ionization chamber and were found to be isotropic. In addition, it was observed that more than one fragment of a fission can emit the same gamma ray.

Stereoscopic viewing of metal foils in the electron microscope. By J. F. Nankivell.
Preliminary results of stereoscopic observations of thin metal foils are reported. The advantages and limitations of this technique are discussed. In polyphase materials, quantitative determinations of foil thickness, number of particles per unit volume, size distribution and relative orientations can be undertaken. The conditions for successful stereoscopic viewing of lattice defects are also considered.

Vertical resolution attainable in electron stereo microscopy. By J. F. Nankivell.
Measurements were carried out to test the validity of Heidenreich and Matheson's relation for the vertical resolution attainable in electron stereomicroscopy. Relative elevations much smaller than this relation would allow were readily detected. Considerations are advanced which indicate that if certain conditions are satisfied, the vertical resolution may approach or even better the lateral resolution of the microscope.

CONFERENCE REPORT

Very low temperature engineering. By D. M. Parkinson.
The 93rd science meeting of the Low Temperature Group took the form of a discussion on 'Low Temperature Engineering' which was led by Mr. Zvegintzov of N.R.D.C. The main issue was that although in Britain cryogenic research involving hydrogen and helium temperatures was well developed, there were no corresponding developments in industry. This topic was thoroughly discussed and a list was drawn up of suggested applications in which industry could take interest. Some of these were well formulated some were still in the idea stage only. During the course of the meeting British Industry was attacked because of supposed lack of enterprise and defended because of the lack of stimulating development contracts. In any event it was agreed that the interested laboratories and industrial concerns must be drawn together.

Journal of Scientific Instruments

Frequency dividing circuit and phase comparator. By E. Archbold.
A pulse counting circuit is described which delivers every *n*th pulse to its output where *n* is any number up to the capacity of the circuit. The phase comparator accepts two pulse trains of the same frequency and measures the phase difference between them to an accuracy of better than four parts in ten thousand.

Parallel movement for high finesse interferometric scanning. By D. J. Bradley.
The design and construction of a parallel strip-spring movement for a high resolution Fabry-Perot spectrometer are described. Scanning frequencies of up to 1000 c/s have been achieved and simultaneous slow and oscillatory scanning is employed. Details are given of tests on the movement. Parallelism is retained to better than 0·02 in. over 5 orders. The driving current–displacement relation is linear to 0·5%, and can be calibrated to 4 times this accuracy. Auxiliary optical and electronic arrangements are also described.

Cryostat for optical measurements between 300°K and 4·2°K. By J. L. Brebner and E. Mooser.
A cryostat is described which permits measurement of the optical properties of solids at any desired temperature between 300°K and 4·2°K. Special attention has been given to the compactness of the sample holder and the surrounding radiation shield so that measurements can be carried out with the sample mounted in the $1\frac{1}{4}$-cm wide gap of an electromagnet.

Radial shear interferometry. By D. S. Brown.
Radial shear interferometry, in which a wavefront is compared with an expanded image of itself, is described and a relation between wavefront aberration and interference pattern derived. Two interferometers are described, one a small radial shears, and an 'exploded shear' type where the expansion is very large. This latter instrument is direct reading in that the wavefront aberrations appear unmodified in the interference pattern.

Apparatus for the rapid scanning of the Seebeck coefficient of semiconductors. By L. E. J. Cowles and L. A. Dauncey.
An apparatus for the determination, near room temperature, of the Seebeck coefficient at a point on the surface of a semiconductor is described. Measurements are simplified by the use of a direct reading potentiometer circuit, and the design of the sample mounting permits rapid measurement at a large number of points.

Apparatus for the differential thermal analysis of compounds with high vapour pressure components. By D. B. Gasson.
The construction and operation of the apparatus is described. Three samples can be analysed at a time. The arrangement of thermocouples permits the use of a standard 16-point print recorder absolute and differential thermocouple voltages to a satisfactory accuracy and sensitivity without recourse to pre-amplifiers.

Micro x-ray diffraction camera for studies of orientation textures and single microcrystals. By J.-E. Glas.
A description is given of an evacuable micro x-ray diffraction camera provided with three different interchangeable specimen holders. This equipment may be used for orientation texture studies, for registration of oscillation and rotation diagrams from single microcrystals as well as for ordinary micro diffraction work.

Temperature controller for use in calorimetry. By D. J. Hamblin and F. E. Karasz.
A reliable temperature controller is described, capable of maintaining the temperature of the furnace surrounding an adiabatic calorimeter assembly to within $\pm 0{\cdot}02$°c. The apparatus is an extension of the 'Mole high-low' type of controller and provides both proportional and reset action.

Double tilting specimen holder for the Siemens Elmiskop I. By G. V. Patser and P. R. Swann.
The device enables electron microscope specimens to be tilted smoothly in any direction up to $\pm 10°$ away from the electron beam axis. The normal specimen level in the objective lens is maintained and hence no loss in resolution arises. Also the specimen holder of the device may be inserted through the usual microscope air-lock. Although the instrument is designed to be used in the Siemens Elmiskop I, the principles employed would be applicable to many other electron microscopes.

Mass spectrometer solid source arrangement for the simultaneous analysis of two samples. By H. Patterson and H. W. Wilson.
The filaments of the usual triple filament assembly used in thermal ionization solid source mass spectrometers have been re-arranged to permit the analyses of two separate samples, on the same filament bead. One of these samples may be a standard.
Smaller isotopic abundance differences can be detected using this new arrangement which confers on a solid source machine some of the advantages of a dual inlet gas machine. It also appears to have a somewhat higher efficiency for the production of ions. Experiments demonstrate the improvement in accuracy, and the absence of cross contamination provided certain precautions are observed.

Constant sensitivity bridge for thermistor thermometers. By E. Pitts and P. T. Priestley.
Despite the variation of the incremental temperature resistance sensitivity of thermistors, temperatures can be measured in a Wheatstone bridge circuit having constant temperature deflection sensitivity if the bridge is fed from a variable voltage supply. In the circuit described the compensation can be automatically set when the bridge is balanced, both operations being performed simultaneously on one and the same variable resistor which is in series with a thermistor in one arm of a Wheatstone bridge and is part of a fixed resistor, the remainder of which is in series with the bridge voltage supply. As a result the voltage across the bridge changes with the balancing resistor so that the rate of change with temperature of the off-balance current is independent of the temperature at which the bridge is balanced. The resistance values of the other three bridge arms must be suitably chosen to achieve this automatic compensation and a method is described for their evaluation. In a typical example full-scale deflection was obtained for a change of $0{\cdot}315$°c, i.e. a sensitivity of $2{\cdot}45\mu$a/°c, which was within 1% of the calculated value and constant to 1% over the working range of 15°c.

Electron energy distribution measurements in gas discharges. By B. W. Smithers.
Signals produced by the current in a Langmuir probe circuit have, when modified by a simple differentiating network, been used to obtain electron energy distribution characteristics. Tuned filters are essential for the elimination of spurious signals, and their required properties are discussed.

Some applications of mercury wetted contact relays. By W. E. Sear, H. P. D. Lanyon and J. Mort.
Within the limitations inherent in mechanical switching devices, mercury wetted contact relays can provide a simple and effective solution to a number of experimental problems. Details of the following applications are given and their limitations are discussed. The generation of msec electron pulses with energies up to 50 kev; the production of fast rising msec voltage pulses of up to ± 1800v; a compact, low capacity gating unit which allows the integration of high voltage pulses in crystal specimens; a counter apparatus, coupled capacitatively to the input of sensitive amplifying equipment; a technique employing two relays which has been used to study the decay of excess carriers injected in an insulating solid by a fast rising voltage step.

Recording equipment for internal friction measurements. By R. L. Stephenson and H. E. McCoy, Jr.
An apparatus has been developed for recording internal friction data in such a manner as to circumvent many of the laborious and time-consuming observations and calculations usually associated with these measurements. As in the conventional method, an optical lever is used. Instead of following the oscillations visually, however, the passage of the beam across the scale is detected by photoconductive cells. The cells are strategically located so that, when their signals are fed through a multichannel switching circuit to the pens of an operation recorder, a plot of the logarithm of the vibrational amplitude versus the number of cycles is recorded on the chart. From the definition of the logarithmic decrement, δ, it can be shown that the slope of this curve is $-\delta$. The apparatus is inexpensive and requires a minimum of maintenance. It has been used for accurate determinations of values of δ from below $0{\cdot}0001$ up to $0{\cdot}3$.

Recording Bourdon gauge manometer. By B. J. Tyler.
A simple modification of a Bourdon spoon gauge is described permitting automatic photoelectric recording of pressure changes. A pressure range of from 0 to 760 mm Hg was available, with a detectable response to changes as low as $0{\cdot}01$ mm Hg.

Proceedings of The Physical Society

The fluorescence and scintillation decay times of crystalline anthracene. By J. B. Birks.
The experimental data are analysed with the following conclusions. The molecular decay time τ_0 of a thin anthracene crystal lamina at room temperature is 10 nsec. The thick crystal values are increased by self-absorption to 31·6 nsec (volume excitation, e.g. by γ-rays), 24·1 nsec (surface excitation, e.g. by ultra-violet or α-rays, and emission observed by transmission) and 19·4 nsec (surface excitation, and observation by reflection). Surface oxidation or reduction in crystal thickness yields lower values. For microcrystals of dimensions comparable with the exciton mean free path ($\sim 0{\cdot}1\mu$), the decay time is reduced below τ_0 due to premature conversion of excitons into photons at the crystal surface.

Studies of the intermediate state in thin superconducting films. By R. F. Broom and E. H. Rhoderick.
Studies of the intermediate state of tin and lead films, 2000 Å thick, in a transverse magnetic field have been made using a Hall-effect probe with a resolution of $\frac{1}{4}$ mm. The magnetization patterns showed structure comparable with the resolution at fields much smaller than the bulk critical field; it is likely that this was not the true domain structure but rather the coarse modulation of a much finer domain spacing due to lack of uniformity in the film. Except when flux trapping occurred, there was no sign of any structure much coarser than the resolution. The magnetization patterns were reproducible under similar conditions with identical magnetic history. As far as their magnetic properties were concerned, the films seemed to be completely normal at fields well below that at which resistance appeared, indicating the persistence of continuous superconducting threads. Hysteresis effects associated with flux trapping were observed, the pattern of the trapped flux being disturbed by the passage of a current. It was also found that a current could generate trapped flux in a virgin film. Measurements of the magnetic field configuration due to a current in a lead strip 2000 Å thick and 1·5 mm wide showed the current to be concentrated at the edges.

Duality of non-planar electric circuits without the use of ideal transformers. By M. Erdei.
In 1945 A. Bloch showed that with the aid of ideal transformers the dual networks can be constructed for any given non-planar networks. In this article it is shown that dual networks can also be obtained by introducing elements with infinite impedances (admitances).

Linear dissipative processes in liquids. By P. Gray.
The mechanism by which molecular momentum and energy in a liquid are dissipated is found to be linear, with friction constant β, if a time τ exists which is long enough for the mean square increment of momentum to be proportional to τ, but so short that $\beta\tau \ll 1$. This is distinguished from earlier, formally identical, results in that τ is less, not greater, than the autocorrelation time of the force.
From the success of calculations based on the assumption of a linear dissipative process, and from the experimental value of the friction constant, it is concluded that the mechanism of self-diffusion is one in which the typical molecule executes a quasi-random walk within the region bounded by its nearest neighbour shell for periods much longer than β^{-1}.

The back-scattering of acoustic waves in water by an obstacle. I. Design of a scale model and investigation of its validity. By R. W. G. Haslett.
A scale model of a marine echo-sounder is described, in which acoustic waves are scattered by fish. The parameters are considered for a model immersed in a tank of fresh water in the laboratory.
A frequency of 1·48 mc/s was chosen. Many measurements were made on standard targets, supports for small obstacles, the sensibly plane-wave region, the variation of acoustic velocity of water after refilling the tank and the signals received from a target of known back-scattering acoustic cross section at various ranges.
As the experimental results show close agreement with calculations from theory the validity of the model is established.

The back-scattering of acoustic waves in water by an obstacle. II. Determination of the reflectivities of solids, using small specimens. By R. W. G. Haslett.
Two methods of measurement of the acoustic reflectivities of solids immersed in water were adapted to specimens in which either two or three of the dimensions were small (e.g. one to ten times the incident wavelength). These methods are particularly relevant to materials which cannot be obtained in sufficient bulk or which are of a flabby nature. The latter can be largely overcome by using small samples.
At a frequency of 1·48 mc/s, determinations were made of the reflectivities of wet fish bone (26%), damp fish tissue (4·6%), Plasticine (44%), soft rubber (11%) and 'pc' rubber (3%), also of their respective densities, whence the velocity of sound in these materials are calculated. The acoustic absorption of Plasticine was also measured (19 db cm^{-1}).
The merits of some of these materials for scale-model experiments are considered.

Observations on narrow showers of mesons below ground. By H. W. Hunter and P. T. Trent.
The decoherence curve of meson showers underground has been studied at depths of 37 and 61 metres water equivalent below sea level at separations from 0·4 m to 10 m, sufficient to overlap earlier measurements at 61 m.w.e. depth which extended to 320 m.
The events recorded may be satisfactorily apportioned between events

produced locally by energetic mesons, and the penetrating component of extensive air showers. The measurements are consistent with the interpretation that the multiple penetrating particles observed in cloud chambers underground represent the high particle-density region of extensive showers of μ-mesons.

The cross section for the production of penetrating showers by μ-mesons at 61 m.w.e. depth is $(4 \pm 2) \times 10^{-33}$cm^2 nucleon^{-1}, for ran energy transfer of 8 gev, in agreement with earlier measurements.

Ultra-violet and visible thermal glow of KCl: Tl phosphors. By R. V. Joshi.

The ultra-violet and visible components of the thermal glow of KCl: Tl phosphors were recorded separately for the study of the distribution of traps with respect to depth. The experimental results obtained help one to understand the correlation between the two principal glow peaks and the two main emission bands of the phosphor. It is suggested that the electrons released from traps corresponding to the 200°k glow peak favour emission in the visible and those released from traps connected with the 300°k glow peak prefer emission in the ultra-violet.

Thin lens aberrations of anamorphotic telescopes. By N. v. d. W. Lessing.

Thin lens equations are derived for the correction of the two aberrations of astigmatism and distortion, resulting from the anamorphotic effect in an anamorphotic telescope, and it is shown that these two aberrations can only be corrected in such a system of *three* thin cylindrical lenses of the available optical glasses, when the angular magnification of the telescope in the first principal section is very close to unity.

Some measurements of the surface properties of silicon by d.c., a.c. and pulsed field effects. By B. R. Marathe.

A.c. field effect measurements on fast surface states on silicon are not possible because the minimum of conductance cannot be observed. The pulsed field effect measurements and the flattening of the a.c. field effect curve are utilized in attempting to interpret the a.c. field effect curve and deduce the density and energy of the surface states.

Superconducting penetration depth measurements in aluminium at 175 Mc/s. By W. L. McLean.

A method is described for finding changes in the penetration depth from changes in the resonant frequency of a helix having a core of the superconductor. Some results have been obtained for pure and impure aluminium samples. At the lowest temperatures that could be reached, there was no significant deviation from a linear variation of the penetration depth λ with $z = (1-t^4)^{-1/3}$. The value of $d\lambda/dz$ in the range $1{\cdot}1 \leqslant z \leqslant 1{\cdot}7$ was found to be $5{\cdot}3 \times 10^{-4}$cm.

Waves on a thin conducting shell in a magnetic field. By J. W. Miles.

Percival's (1960) analysis for a flat sheet is extended to thin (compared with the skin depth) shells. Specific application is made to axially symmetric waves on a circular, cylindrical shell placed in an axial magnetic field. It is concluded that magnetically supported waves of sufficient length should be observable if the shell can be weakened in such a way as to keep the hoop stress at or near zero.

New representation of wave field. By K. Miyamoto.

A new vector potential $\mathbf{W}(\mathrm{Q}, \mathrm{P}; t)$ is associated with a general scalar wave field $U(\mathrm{P}, t)$ of any prescribed time dependence. This potential has the property that the normal component of its curl, taken with respect to the coordinates of any point Q on a closed surface S surrounding an observing point P, is equal to the integrand of the generalized Helmholtz–Kirchhoff integral; that is

$$U(\mathrm{P}, t) = \int_S \mathbf{V}(\mathrm{Q}, \mathrm{P}; t) \cdot \mathbf{n}\, dS,$$

$$\mathbf{W}(\mathrm{Q}, \mathrm{P}; t) = \operatorname{curl} \mathbf{V}(\mathrm{Q}, \mathrm{P}; t),$$

where $\mathbf{n}$ is the normal to S.

The closed expression of the vector potential is derived, that is

$$\mathbf{W}(\mathrm{Q}, \mathrm{P}; t) = \frac{\hat{\mathbf{s}}}{4\pi s} \wedge \int_{s_0}^{s} [\operatorname{grad} U(\mathbf{r}' - \rho\hat{\mathbf{s}}, t')]\, d\rho + \mathbf{W}_{s_0},$$

where $\mathbf{r}'$, $\mathbf{r}$ are the coordinates of Q and P respectively, $t' = t - \rho/c$, $\mathbf{s} = \mathbf{r}' - \mathbf{r}$ and $\hat{\mathbf{s}} = \mathbf{s}/s$. $\mathbf{W}_{s_0}$ is an additional contribution and c is the velocity of light. This general formula is applied to non-monochromatic plane and spherical waves.

These theorems provide the possibility of the transformation of the Kirchhoff diffraction integral (two dimensional integral) to the line integral and may be regarded as a generalization of Maggi–Rubinowicz's diffraction wave to the general cases.

A coefficient of friction which increases with increasing load. Results with undrawn nylon monofilaments, and a theoretical explanation. By J. Molgaard.

Results for the frictional force of 64 denier undrawn nylon monofilaments running against rigid cylinders showed an increase in the coefficient of friction with increasing load, i.e., in the formula $F = \alpha W^n$ relating friction and normal load, n is greater than one. This can be explained by a large increase in the number of asperities making contact as the load is increased, as is shown by experiments with rubber models and theoretical considerations.

The electrical properties of nickel ferrite containing a manganese impurity. By R. Parker and H. Lord.

Electrical resistivity and thermoelectric measurements were made on ferrites of nominal compositions $\mathrm{Ni_1\ Fe_{1+\delta}\ Mn_{1-\delta}O_4}$ and $\mathrm{Ni\ Fe_{1+\delta}Mn_{\delta-\delta}O_4}$ prepared at various sintering temperatures and at oxygen pressures of up to six atmospheres. The results show that in certain composition ranges the manganese atoms suppress the easy conduction mechanism involving ions of the same element in different valence states. The detailed relationship between electrical properties and sintering pressures of specimens is found to be unexpectedly complex and suggests that hitherto unsuspected factors determine the conduction process.

Variation of Townsend's second coefficient in an electrodeless discharge in a crossed electric and magnetic field. By S. N. Sen and A. K. Ghosh.

From measurement of breakdown potentials in an electrodeless discharge in a magnetic field the values of γ_H, the Townsend's second coefficient in a magnetic field have been calculated and the curve between γ_H and H has been found to be hyperbolic in nature, for three different values of pressure, 10μ, 25μ and $57{\cdot}5\mu$, the magnetic field varying from 0 to 60 gauss. Assuming the expression $\gamma = A'(E/p) - B'(E/p) - C'$ as derived by Sen and Ghosh in 1961, an expression has been deduced for the variation of γ_H with magnetic field in an electrodeless discharge. The formula thus deduced can explain the observed variation of γ_H with magnetic field and the quantitative agreement is also satisfactory. It is suggested that the incorporation of the variation of γ_H with magnetic field together with the concept of equivalent pressure will explain the observed experimental results better.

The Rydberg–Klein–Rees method of constructing the true potential energy curves of diatomic molecules. By N. L. Singh and D. C. Jain.

Alternative simplified expressions have been deduced for 'f' and 'g' involved in the calculation of the true potential energy curves of such electronic states of diatomic molecules whose vibrational terms can not be adequately represented by a quadratic in $(v + \frac{1}{2})$. These expressions have been used in calculating the true potential curve of the $a^3\Pi_{0^+}$ state of $^{79}\mathrm{Br}^{79}\mathrm{Br}$ molecule and the results show a close agreement with those obtained by Rees in 1947. The true potential energy curve of the $A^1\Sigma^+$ state of LiH molecule has also been calculated by the present method and the results are found to agree quite well with those obtained by Fallon, Vanderslice and Mahon in 1960.

Errors of finite probe size in the determination of electron energy distribution functions. By J. D. Swift.

The corrections which are necessary in the measurement, by means of a spherical Langmuir probe, of the energy distribution function $f_e(U)$ of the electrons in a plasma are analysed. The principal effect considered here is the disturbance of the plasma produced by the drain of electrons to the probe. This disturbance becomes increasingly serious as the gas pressure p and the probe radius a increase and as U decreases. It is shown that the true value of $f_e(U)$ differs by less than 25% from that determined from the simple theory neglecting the disturbance provided $U \geqslant \frac{1}{2}\bar{U}$ and $a < \frac{1}{2}l_e$ where l_e is the electron mean free path.

The surface impedance of superconducting aluminium at 3 G c/s. By D. Llewelyn Williams.

In an attempt to find the anisotropy of the penetration depth in superconducting aluminium, such as would confirm a non-local relation between field and current, high-frequency measurements have been made on single crystal wires of different orientations. No strong evidence for anisotropy has appeared, and there is some evidence from the measurements of surface resistance that the crystals used may not have had the best orientations to reveal any effect. The behaviour of the surface resistance and reactance has been carefully studied very near the transition temperature, and the latter has been found to show a maximum just below T_c. There is qualitative but not quantitative agreement with the predictions of theory.

LETTERS TO THE EDITOR

Absorption of coesite in the region of 5–20 microns. By I. G. Austin, H. A. Gebbie and I. Morin.

Localized electron eigenstates in one-dimensional liquids. By R. E. B. Makinson and A. P. Roberts.

σ-bonding in $(\mathrm{CuCl_4})^{4-}$. By J. H. M. Thornley, B. W. Mangum J. H. E. Griffiths and J. Owen.

Failure of the Heisenberg model of ferromagnetism in nickel. By J. F. W. Mallett.

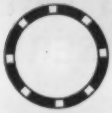
The structures of $\mathrm{NaNbO_3}$ and $\mathrm{Na_{x-0{\cdot}1}K_{x-0{\cdot}1}NbO_3}$. By M. Wells and Helen D. Megaw.

Effect of variations in the quantum counting efficiency of detectors on the mean wavelength of X-ray emission lines. By A. J. C. Wilson and B. W. Delf.

Damping of sound waves by an ideally rough surface. By H. J. Wintle.

Normal vibrations in sodium. By A. D. B. Woods, B. N. Brockhouse R. H. March and R. Bowers.

NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE



OPPORTUNITIES FOR EXPERIMENTAL PHYSICISTS AND ENGINEERS

AT THE RUTHERFORD HIGH ENERGY LABORATORY

The Rutherford High Energy Laboratory, Harwell, Berks., will provide facilities for nuclear research to universities and similar institutions—facilities so large or complex in their development that they are beyond the scope of individual universities. This opens up new opportunities to Physicists and Engineers for high energy research. Applications are invited against the following vacancies:—

SENIOR SCIENTIFIC OFFICER/PRINCIPAL SCIENTIFIC OFFICER
(ELECTROSTATIC GENERATOR GROUP)

Two vacancies exist at Principal or Senior Scientific Officer level to assist in the development of the machines required for the Oxford University nuclear structure project. Two machines are involved: a horizontal tandem, to be purchased commercially; and a vertical machine capable of operating up to 8 million volts. It is the responsibility of the group to develop the vertical machine, to provide ion sources, bending magnets and beam paths for both machines, and to undertake installation and commissioning of the whole. These vacancies are in:—

ION SOURCE DEVELOPMENT (Ref. VN. 84A/110)

One source at earth potential will provide negative ions for the tandem; the other, at high potential under pressure, will provide negative or positive ions for the vertical machine.

For this post, previous research experience in gas discharge physics, preferably in connection with ion source development, is required.

MACHINE DEVELOPMENT (Ref. VN. 84B/110)

The successful candidate will be required to undertake developmental studies connected with the machine. These studies will be concerned with corona and spark breakdown phenomena in high pressure gas; breakdown and microdischarges in relation to accelerating tube structures; stabilization systems; and beam optics, particularly with reference to 90° deflecting magnets and quadrupole lens systems.

Preference will be given to candidates with experience in some of these fields.

SCIENTIFIC OFFICER/SENIOR SCIENTIFIC OFFICER
(RADIO FREQUENCY GROUP)

There are two or more vacancies in The Radio Frequency Group, concerned principally with the design and construction of the radio frequency equipment for the 7,000 MeV Synchrotron, NIMROD; also with the study of accelerating systems for future high energy machines.

BEAM CONTROL (Ref. VN. 85A/110)

To assist in beam control, beam diagnostics, particle dynamics, etc. The work includes a theoretical study of dynamics of particles in the machine, the design of fast electronic pulse circuitry and development of particle detection techniques.

Experience in electronic circuit design is desirable but not essential.

ACCELERATING STRUCTURE DEVELOPMENT (Ref. VN. 85B/110)

To develop accelerating structures for future high energy machines. This involves a knowledge of electromagnetic theory and microwave techniques. Previous experience in this field is desirable but not essential.

CYCLOTRON GROUP (Ref. VN. 86/110)

There is a vacancy for a Physicist, preferably with a Ph.D. or a few years postgraduate experience, to do basic experimental studies of particle dynamics in the central region of a "Spiral-Ridge" cyclotron, and/or to develop ion sources for producing multiply-charged heavy ions. A small operating cyclotron will be available for this work; technical assistance will be provided together with access to a Mercury computer if necessary. The project offers scope for a man with an ingenious and inventive approach, who is able to work out the details of his own programme.

ELECTRONICS GROUP (Ref. VN. 91/110)

There are vacancies in this group, which is being established to develop electronic circuitry primarily for future nuclear physics experiments on the 7,000 MeV Synchrotron, NIMROD, involving a variety of electronic techniques. Experience of high speed pulse circuitry will be an advantage.

Applicants for all posts should possess good University Honours degrees in Physics or Electrical Engineering. Successful candidates will be offered permanent appointments to the Scientific Officer Class at salaries in the scales:—

SCIENTIFIC OFFICER.....£790-£1,310
SENIOR SCIENTIFIC OFFICER.....£1,440-£1,770
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according to qualifications and experience: these appointments will be pensionable under the U.K.A.E.A. Non Industrial Superannuation Scheme.

For candidates who would prefer an appointment for a period of years rather than a permanent appointment, for example because they are looking towards a career at a University, Fixed Term Research appointments for periods of up to five years are available. These would be at salaries similar to those of the Scientific Officer class with superannuation under F.S.S.U.

Apply by letter to the Secretary

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Please apply, giving full details and quoting two referees (past and, if possible, present employers) to the Director of Labour and Welfare, Central Electricity Generating Board, 825 Wilmslow Road, East Didsbury, Manchester 20, quoting reference No. E.74/597B.

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The construction of optical masers and their applications in industrial instrumentation are under investigation at the

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Please write, giving brief details of qualifications and experience and quoting ref. KMG., to the

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Applications, quoting reference TPF, to the Director,

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BS

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Applications are invited from candidates with an honours degree in Physics or equivalent qualifications for D.S.I.R. Research Assistantship at a salary of £800 per annum. The successful applicant will assist in research work on high current discharges. Experience in electronics or some branch of plasma physics is desirable. Application forms may be obtained from the Secretary of the College.

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Applications are invited for a LECTURESHIP OR ASSISTANTSHIP IN PHYSICS in the Department of Physics, Queen's College, Dundee, with effect from a date to be arranged. Preference will be given to a candidate with special interest in Solid State Physics. Salary scales: Lectureship — £1,050 × £50 – £1,400 (efficiency bar) × £75 – £1,850; Assistantship — £800 × £50 – £950. F.S.S.U.; Family Allowance and grant towards furniture removal expenses. Applications (six copies) containing the names of three referees to be lodged not later than Monday, January 8, 1962, with the Secretary of the University, Queen's College, Dundee, from whom further particulars may be obtained.

PHYSICIST required, age 25-35, with good degree and some experience in electrical discharge phenomena in gases for studies in this field and design and development of corresponding equipment. Five-day week. Please write quoting No. 36, to: Personnel Officer, The British Oxygen Co. Ltd., Scientific Division, Deer Park Road, London, S.W.19.

COURSES

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A course of about 30 postgraduate lectures on PLASMA PHYSICS will be given in the Physics Department by Dr. R. Latham and members of the High Temperature Physics Group on Fridays at 2.30 p.m. commencing January 12, 1962. Further details from the Registrar, Imperial College.

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Deputy Secretary, The Institute of Physics and The Physical Society

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